January 1955

NUCLEONICS

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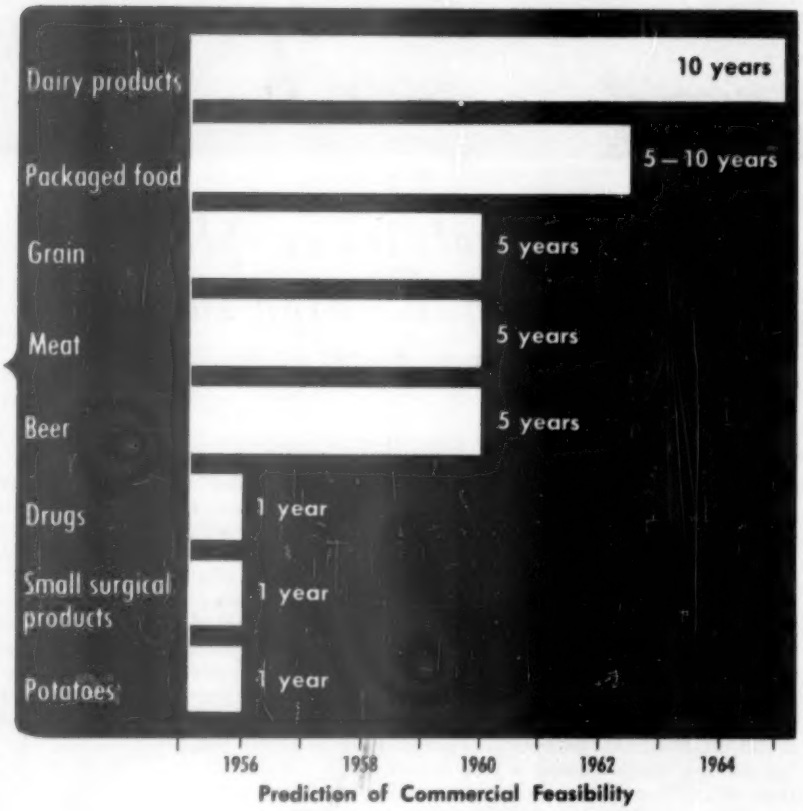

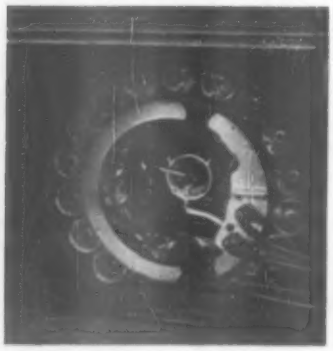

Carbon dioxide counting extends dating to 45,000 years

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NUCLEONICS

JANUARY • 1955

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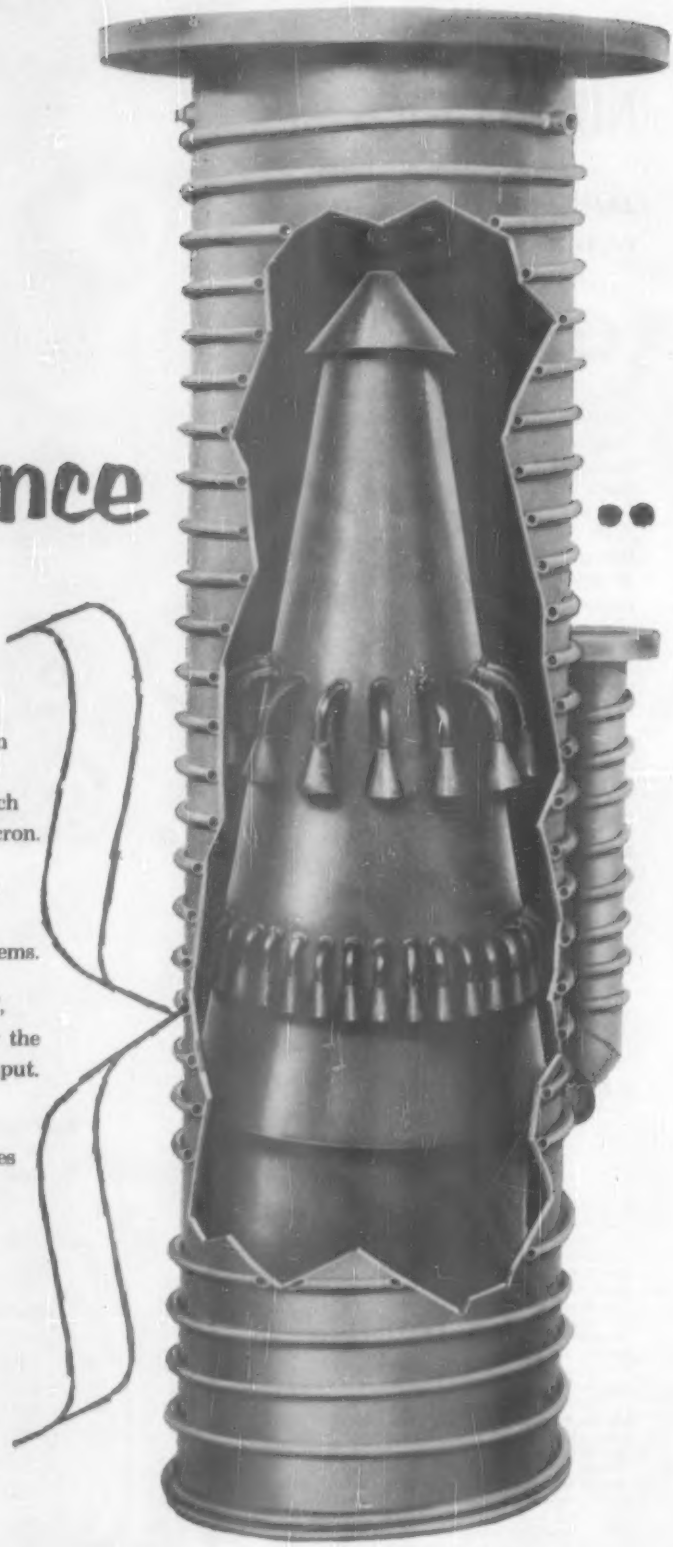
Major Advance ..



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Increased pumping speeds, shorter pumping cycles, smaller mechanical pumps, operation against higher forepressures, are outstanding advantages of the new Stokes Ring-Jet Pumps. Fill out the coupon for full information.

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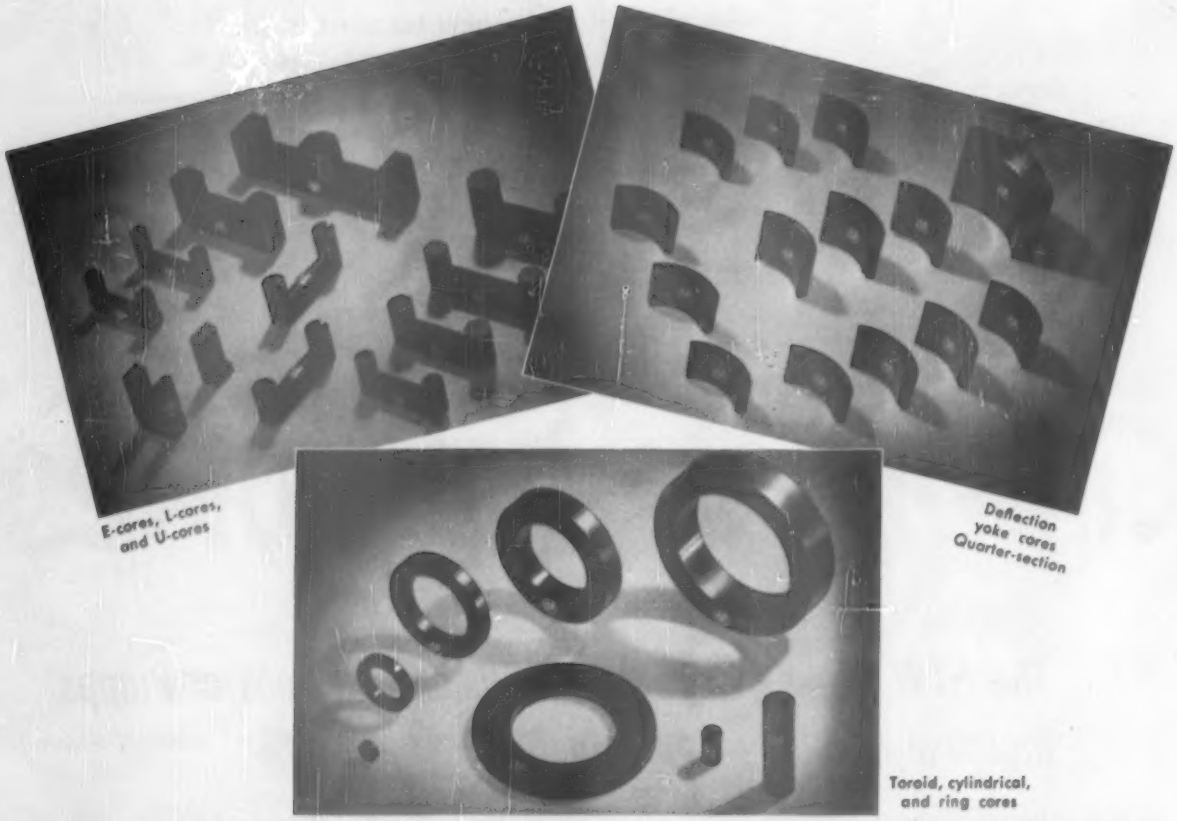
*Patents Pending



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Toroid, cylindrical, and ring cores

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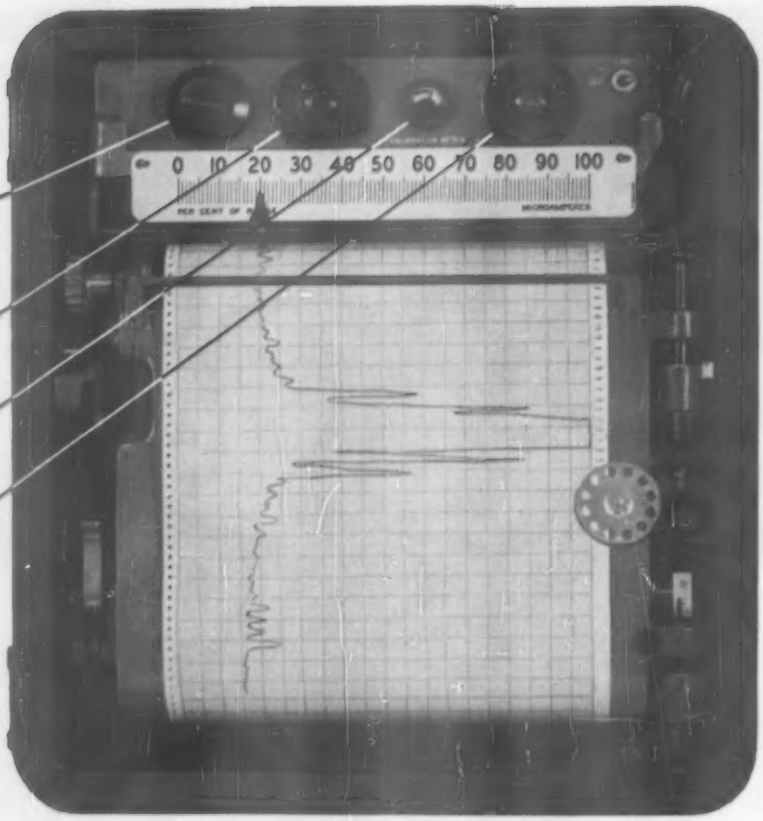
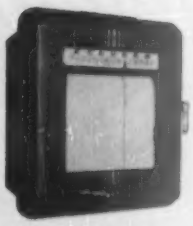

0 10 20 30 40 50 60 70 80 90 100
Range switch for input circuit having values of 0.004, 0.012, 0.04 and 0.12 microampere.
Manually operated zero adjuster for continuous zero suppression of "dark current", independent of range.
Battery Condition Indicator
Manually operated battery rheostat for adjusting range.

Scintillation Counter Tube Output

measured directly

with this Speedomax® Recorder



● Here is a recorder that connects *directly* to Multiplier Phototubes measuring low levels of light as found in scintillation counting, ultra-violet and visible radiation, Raman spectroscopy, and light scattering studies. As a result, the usual separate pre-amplifier is completely eliminated. The recorder has a high-gain, low-level detector-amplifier that provides direct measurement of currents as small as 4 x 10^{-9} ampere full scale.

How it operates

The instrument has four working ranges, 0.004, 0.012, 0.04 and 0.12 microampere full scale, to record a wide range of counter outputs. To change the range, the operator merely turns a manually-operated switch and the record continues within the span of the chart. It is not even necessary to stop the Recorder.

Other features of this Speedomax Recorder include: a range of sensitivity from 0 to 0.004 microampere, a 4, 3 or 2 second balancing speed (full scale) and a chart speed of 120 inches per hour. This instrument is the member of the Speedomax family designed specifically for use with Multiplier Phototubes.

For further information, please contact our nearest district office or write us at 4936 Stenton Ave., Philadelphia 44, Pa.

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WHITE PLAINS 8-5800 **NDA_** NUCLEAR DEVELOPMENT ASSOCIATES, INC.
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G.E. Designs New Alpha Particle Detector for Health Monitoring Against Radiation

General Electric's new alpha particle detector is a dependable monitor for inspecting clothing, machinery, laboratory areas or equipment suspected of containing alpha radiation.

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COMPACT CONSTRUCTION consists of a zinc-sulphide phosphor, photomultiplier tube and cathode follower pre-amplifier giving 0.25 volt output pulses. These pulses are transmitted to a scaler or rate meter. The detector also makes a rapid and sensitive survey meter when connected with a simple audio-speaker, which produces an audio "popping" noise.

PRICE is $249.60* and the detector is available from stock. For further information contact nearest G-E Apparatus Sales Office, or write for Bulletin GEA-6117, Section 605-81, General Electric, Schenectady 5, N.Y.

**Manufacturer's suggested retail price.*

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LATE NEWS and COMMENTARY

Research Reactors Plans are jelling on a number of research reactor projects:

¶Washington State College has given General Electric a reactor study contract.

¶MIT has earmarked $1-million for construction of reactor and building and operation for 5 years. These funds would be adequate for a swimming pool reactor. But there is feeling at MIT that the Argonne CP-5 type is safer and more appropriate for their needs. Thus, another $½-million is being requested to build such a reactor.

¶Although Bendix Aviation has completed its engineering contract for the Watertown Arsenal reactor, the project is essentially at a standstill because of lack of funds for construction.

¶Rice, Houston and Texas A & M are investigating the possibility of cooperatively building a research reactor with money supplied by a local foundation.

¶Ohio State is considering possibility of having a reactor within 5 years.

¶Battelle Memorial Institute plans to let a contract for its 1-Mw swimming pool by Feb. 1—wants it operating by early '56. They plan to supervise the job themselves. Bids have been asked for in three parts: (a) instruments and controls, (b) cooling system and (c) design of reactor and pool. Same contractor might get whole job.

•

AEC Information Policy Feeling is increasing among industrial study teams operating under contract with AEC that AEC's policies on public release of information by the teams are too restrictive. A recent AEC edict said: "All public statements planned by your company is connection with the studies should be forwarded to AEC before release." In enforcement, this apparently has been covering release of material unrelated to actual studies—e.g., general talks on economics of nuclear power.

•

Industrial Test Reactor AEC is seeking industry reaction to the idea of industry's building a test reactor. To encourage such thinking, AEC has told some companies that AEC "might" contract to use 50% of the reactor's space in the first five years. AEC has in mind a 75-Mw MTR-type reactor that would cost about $15-million and could be located in the East.

•

Fallout Quite a conflict has been going on within Federal government circles on what if anything should be said in public on the very sensitive subject of radioactive fallout from weapons tests. Ever since the unfortunate Japanese injuries from fallout from the March 1st hydrogen bomb test, there has been growing public clamor for detailed statements on the over-all subject. Not long ago, the high-level National Security Council reportedly rejected public discussion of the subject. But last month's announcement by Admiral Strauss, AEC chairman, that he would hold a press conference (or possibly it will be a Presidential press conference) on fallout indicates a reversal of thinking. Now the question is how far will AEC go on releasing details. Some would like to see release of fallout data obtained at stations within and outside of continental U. S.

•

Radioiodine Plant A new, $200,000 separations plant for recovering radioactive iodine-131 from uranium fuel slugs has gone into operation at Oak Ridge National Laboratory. The design capacity is 25 curies per week, compared with the previous plant's 3 curies per week. In 8½ years of business, AEC has sold 2,541 curies of I-131. The annual rate is now about 500 curies. With I-131 selling at $0.75 per millicurie, the annual gross income for the plant could be about $375,000.

LATE NEWS (Continued)

Savannah River Reactors Sensitivity of Savannah River reactors, reportedly AEC's most advanced production plants, is apparently decreasing, for AEC has removed from the restricted data category information on "bare or canned slugs including all information obtainable by destructive analysis, dimension specification and cladding or canning equipment."

•

Japanese Tour Fourteen Japanese specialists are visiting Italy, Switzerland, France, West Germany, Holland, Denmark, Norway, Sweden, England, Canada and the U. S. to get information on atomic energy developments. They are seeking information on reactors, administrative problems, heavy water, nuclear chemistry, metallurgy and geology of uranium.

•

To Use S.I.R. Power General Electric has requested permission to generate electricity from the power produced by the *Sea Wolf* prototype reactor being built by GE at West Milton, N. Y. AEC and Navy Bureau of Ships have reportedly indicated no objection.

•

Reactor School It is expected that the U. S. reactor school for foreign students will start at Argonne National Laboratory in March with about 20 students.

•

International Conference The first get-together of nations to implement international cooperation in atomic energy will be in New York City on January 17. Representatives of the U. S., Canada, England, France, India, Russia and Brazil will meet to work out details of the forthcoming United Nations nuclear energy conference.

One of the main questions to be resolved is just what the conference should cover. As in other areas of international relationships, there will be sparring among the nations, with each trying to determine how far the others are willing to go on revealing technology.

Basically, as pointed out by Mr. Strauss on p. 77, the conference will deal with reactor technology, uses of radiation, and basic nuelear science. One possible basis for disagreement among the planners is the extent of coverage of reactor technology. Some Europeans want main emphasis on reactors, particularly data on planned power facilities. One leading American says no one knows how to build power reactors; thus why go into details.

The U. S. point of view on the conference is: it should cover entire field, with radioisotopes being more important than power to some countries; one big purpose is to bring scientists together; it is not necessary to have a major declassification to make the meeting a success; we must balance the advantages of exchanging information via bilateral agreements as against "doing a striptease" at the conference.

According to one American, the U. S. should go into this conference in the same way industry sends employees to give papers at technical conference—they protect trade secrets, latest technology.

Attendance at the reactor sessions will be strictly limited. Radioisotope sessions will be open. About 30–50 Americans will probably be invited.

•

First Nuclear Exhibit The first full-fledged nuclear exhibit covering the entire industry will be sponsored by the Atomic Industrial Forum next September. To be an annual affair, this first show is expected to attract a sizable number of exhibitors, including designers and builders of reactors, manufacturers of reactor components and associated equipment and instruments, and the industries serving the nuclear field. Details from Forum at 280 Madison Ave., New York.

NUCLEONICS JANUARY, 1955

Jerome D. Luntz, *Editor*

Shedding Light on the Law

As we enter 1955, we have had a new atomic energy law for four months. Although it is obvious that the impact of the legislation on the domestic and international scenes will be major, it is far from clear what the precise effect of the law upon the industry and the technology will be.

This stems, in part, from the fact that much mystery surrounds the meaning of key parts of the new law. On the one hand, the intent of Congress in writing certain provisions into the law is not clear because most of the Congressional debate was not on the details of the law itself. On the other hand, the Atomic Energy Commission, the agency charged with responsibility for interpretation and implementation of the law, has not yet advanced far enough in its preparation of regulations.

Light will be shed on both Congressional intent and AEC interpretation in the next several months. Starting in this issue, Nucleonics is pleased to present the first of a series of very significant articles on "The Meaning of the New Atomic Law" by W. Sterling Cole, chairman of the Joint Committee on Atomic Energy in the past Congress. And some time next month, the JCAE will hold hearings called for by the law "for the purpose of receiving information concerning the development, growth, and state of the atomic energy industry."

In his first article, Mr. Cole concentrates on the informational provisions of the law and thereby emphasizes the considerable importance of information dissemination to the growth of the industry. He places great stress on Congressional intent to give AEC wider latitude in making both classified and unclassified information more available. We infer from what he says that most information on nonmilitary uses of atomic energy is either declassifiable or nonsensitive and suggests the desirability of building high fences around the military information and giving wider access to the nonsensitive data. In providing for the so-called "gray area" of nonsensitive classified information, Mr. Cole emphasizes that this was not intended to replace declassification but rather is to be a step in that direction.

Another section that bears out the importance of openness in this field and would foster constructive criticism of the atomic energy program is one that, according to Mr. Cole, is designed to restrict AEC's power to regulate nonsecurity information.

The forthcoming hearings, which the law requires the JCAE to hold in the first 60 days of each new session of Congress, are aimed at providing a "command-performance" forum where all views on the workings of the new law can be aired. We believe that the intent of this provision is in line with the recommendation Nucleonics made in testimony before the JCAE last year:

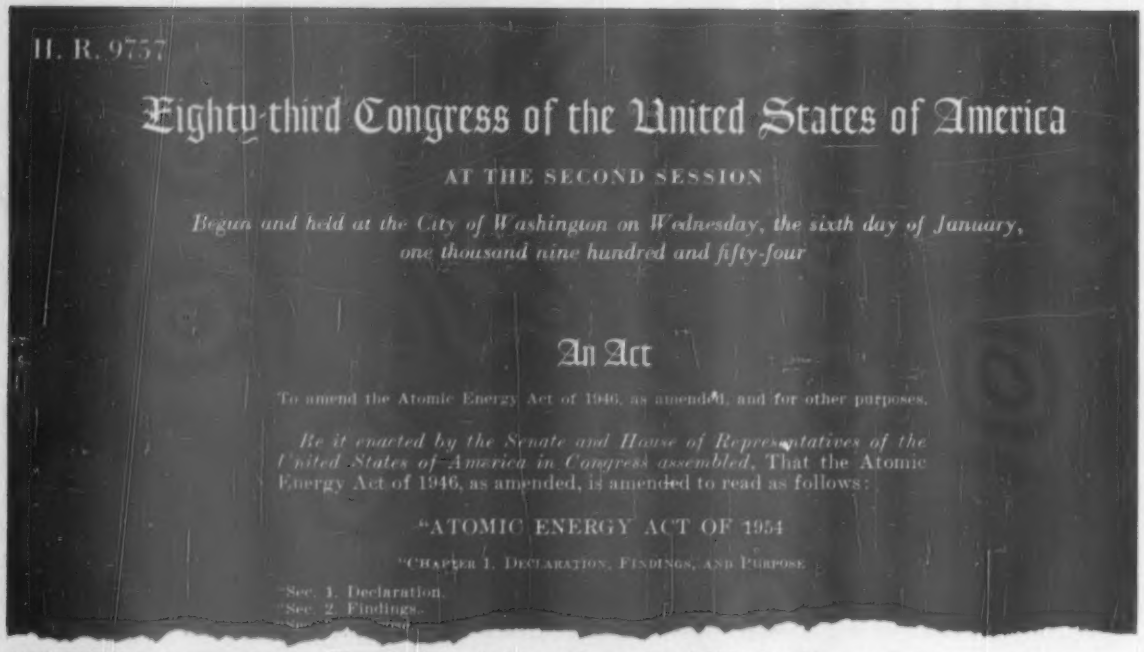
> "Nucleonics recommends that the Joint Committee hold hearings at least once a year specifically for the purpose of examining the administrative functionings of such things as the licensing and leasing provisions. . . . It might be found that the intent of the committee to expedite the development of an American atomic energy industry might not be fully realized because of the lack of specificity of these provisions. Nucleonics believes that AEC and industry would welcome the opportunity of appearing at such hearings on the initiative of the Joint Committee."

The requirement of these hearings has already served as a prod to AEC. The Commission has set the occasion as a target date by which it hopes to discuss its first set of rules and regulations. At the same time, we hope AEC will discuss such things as: its organizational setup for handling matters under the new law, procedures for obtaining different types of licenses, criteria for procuring "L" clearances, prices to be charged for leasing fissionable material and prices to be paid for fissionable material produced by industry, methods for doing business abroad, etc.

Industry, although it's waiting for issuance of AEC regulations, should also be ready to do some talking. We're sure the JCAE will welcome constructive criticisms on the legislation.

And because the hearings are to reveal the "state of the industry," it would be useful if both AEC and industry would report on where we stand technically. One composite picture that's never been presented and that would fit in well would be status reports from each of the industrial study teams on their thinking and planning at the moment.

Every effort should be made to have as much of the hearings as possible held in public. In this formative stage, it is imperative that the development of atomic energy policies be subjected to the widest public purview.



H. R. 9757

Eighty-third Congress of the United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Wednesday, the sixth day of January, one thousand nine hundred and fifty-four

An Act

To amend the Atomic Energy Act of 1946, as amended, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Atomic Energy Act of 1946, as amended, is amended to read as follows:

"ATOMIC ENERGY ACT OF 1954

"CHAPTER 1. DECLARATION, FINDINGS, AND PURPOSE

"Sec. 1. Declaration.
"Sec. 2. Findings.

REPRODUCTION of engrossed copy of first page (above) of Atomic Energy Act of 1954; (right) last page of document, showing signatures of President Eisenhower; Rep. Joseph Martin, Speaker of the House; and Richard Nixon, Vice President

W. Sterling Cole

INTERPRETS

The Meaning of

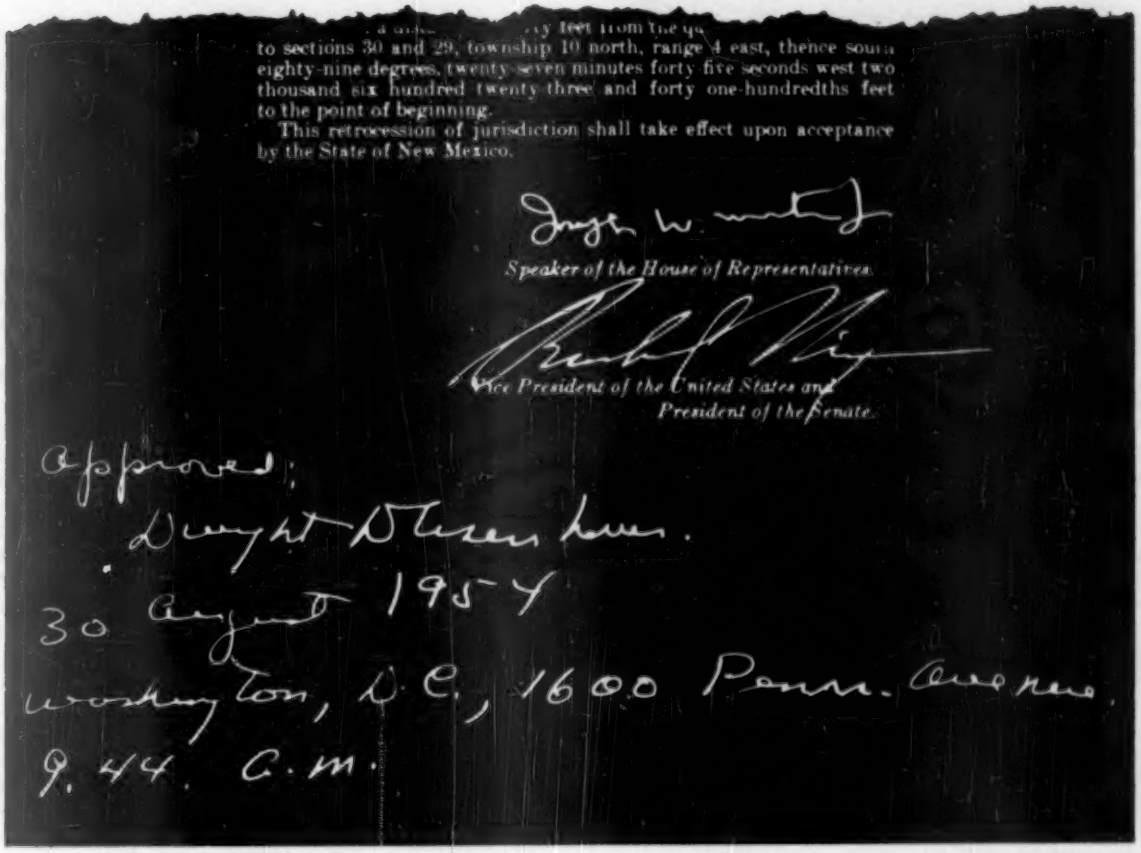
This special series of articles interpreting the Cole-Hickenlooper law has been prepared at the request of NUCLEONICS by Rep. W. Sterling Cole (R., N. Y.), principal architect of the law and chairman of the Joint Committee on Atomic Energy in the 83rd Congress. The editors asked Mr. Cole to emphasize the intent of Congress in changing the law and to relate these changes to industrial development.

"APPROVED: Dwight D. Eisenhower; 30 August 1954; Washington, D. C., 1600 Penn. Avenue; 9:44. A.M."

So wrote President Eisenhower in approving the Atomic Energy Act of 1954 (Public Law 703), and as he lifted his pen from the engrossed bill the result of eighteen months of intensive legislative consideration and debate became the law of the land.

And with the same penstroke the atom was freed from the confining strictures of total Government monopoly and set along the path to commercial development. Perhaps no single law will affect so deeply our way of life—and that of all mankind—as will the new atomic energy act. Domestically, it provides the means of returning this vast new field, so full of import for us all, to the normal channels of industry (excepting, of course, those aspects of the field that are still of high security significance). Internationally, it opens the way for cooperation with friendly nations on the peacetime uses of atomic energy, and provides a channel of information on atomic weapons effects and like matters to our NATO allies and to similar regional defense organizations to which we are a party.

The new law resulted from the studied conclusion of the Joint Committee on Atomic Energy, and of the two Houses of Congress, that the McMahon Act, passed in 1946, no longer would best serve our national needs. If we were to enjoy speedily the benefits of atomic power and maintain our international leadership, it was in our highest national


to sections 30 and 29, township 10 north, range 4 east, thence south eighty-nine degrees, twenty-seven minutes forty five seconds west two thousand six hundred twenty-three and forty one-hundredths feet to the point of beginning.

This retrocession of jurisdiction shall take effect upon acceptance by the State of New Mexico.

Speaker of the House of Representatives.

Vice President of the United States and President of the Senate.

Approved:
Dwight D. Eisenhower.
30 August 1954
Washington, D. C., 1600 Penna. Avenue.
9.44 A.M.

the New Atomic Law–I

interest to provide for active participation in that development by private enterprise. In a word, the time had come to let private enterprise go to work, with truly private sponsorship and support and, it was hoped, with its traditional enterprise and zeal, sharpened with the outlook for honestly-earned profit. This is of course not to say that in passing this new law the Congress intended or contemplated that Government-sponsored developmental programs should be limited or curtailed. The converse is the case as was re-emphasized by Committee of Conference amendments to section 31 a.4 (relating to government support for nuclear power development), which will be discussed in a later article.

In the new law, therefore, private enterprise is encouraged to enter into full partnership with the Government and to help carry the development of this field forward both within this country and abroad. Under the new Act, for the first time, industrial participants can possess under license special nuclear materials, can own licensed facilities for utilization or production of such materials, can have access to classified information, and can obtain patents on their independent research work.

It is our clear hope that under such stimuli private enterprise will participate more freely in the program, bringing to it that type of progress which it has brought to the other fields of scientific development in this country.

Up to the time of the passage of the new Act, not only was title to all special nuclear materials vested in the United States, but only the Atomic Energy Commission was allowed to possess them or to use them. Under the former law, no one could own a reactor, except for small research reactors not capable of making special nuclear materials in quantities sufficient to make an atomic weapon within a reasonable time. Even in this situation, however, the old law compelled AEC to have at the reactor one of its employees who would have legal possession of the small amounts of special nuclear material involved. This is no longer required by the new Act, and responsible business companies can own reactors and utilize them under license in their normal business activities. From such use will come more important information

WHAT'S COMING

In this introductory article, Mr. Cole points out how the law is intended to encourage the development of an industry and how it is designed to meet the information requirements of the industry. Next month's article will be concerned with the licensing provisions. Among others, such questions as these will be answered by Mr. Cole:

1. *What are "utilization or production facilities"?*
2. *What is a "finding of practical value" as related to nuclear power plants?*
3. *What types of facilities would require "commercial" licenses and what type "development"?*
4. *What is intended by "minimum regulations" imposed on "development" licenses?*

Subsequent articles will cover provisions of the law on: fuel availability and pricing, patents, international relations, research, etc.

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concerning operation of reactors and more research and development work to add to our national storehouse of information on the nonmilitary use of atomic energy. By adding to these opportunities the ability to obtain patents on the nonmilitary uses of atomic energy, it is hoped that there will be considerable incentive to business firms to enter the atomic energy field and to participate in its development.

However, none of these incentives would have been of importance without the changes in the Act that permit and encourage freer dissemination of technical information in the field, and, at the same time, preserve needed security safeguards. For the purposes of this discussion, these changes (which are dealt with in this article only in the light of the domestic problems) are treated in seven categories in the following pages.

The main purpose in revising the control of information aspects of the law was to bring the basic premises of the provisions of the law into accord with current conditions. Therefore, the statutory provisions were drafted so as to enable the Commission to direct itself to determining the type of information that it is essential to protect, and then concentrate on the protection of that information. That is to say, the underlying principle was to sharpen protection where it is really important, and moderate it where it is less important.

In the remainder of this article, I shall treat with the information control provisions of the new law as they concern domestic activities.

Restatement of Purposes of Controlling Information

A significant change in emphasis is incorporated in Section 31. of the Act so as to establish a two-fold information control program. Whereas in the McMahon Act the program was directed toward the "control of scientific and technical information which will permit the dissemination of such information to encourage scientific progress . . . ," the new Act in positive words establishes a program "for the dissemination of unclassified scientific and technical information." It also spells out that in the case of Restricted Data, there shall be a program "for the control, dissemination and declassification" of such data "subject to appropriate safeguards." Both activities (i.e., dissemination of unclassified information and the control, dissemination and declassification of Restricted Data) are to be carried out so as to "encourage" not only "scientific" but also "industrial" progress.

In the sections dealing with Control of Information (Chapter 12) other substantial changes are made. Under the old Act, no information with respect to industrial uses of atomic energy was to be communicated to another nation until there were enforceable international safeguards against the use of atomic energy for destructive purposes. Although the new Act generally prohibits the international communication of any Restricted Data, it also provides a safe, specific, and workable mechanism to accomplish exchange of certain types of Restricted Data under carefully controlled conditions. It no longer ties the transmittal of Restricted Data to the existence of international controls on weapons.

The positive policy principle governing the dissemination of technical information is no longer limited to "provide that free interchange of ideas and criticisms which is essential to scientific progress." As in Section 3b., the objective is expanded to include "industrial progress" as well as "scientific progress." In addition, it is the purpose of the control of information provisions to "enlarge the fund of technical information." Most importantly, however, the objectives of the information program have been expanded to include the fostering of "public understanding." In our form of Government where every citizen has the right to indicate his attitude on important issues, an educated and understanding public is essential. But the atomic energy program has been established as a government monopoly and continued under necessary shrouds of secrecy. Since, under the new law, more normal industrial participation is encouraged in the atomic energy program, it is vital that, commensurate with the real needs of security, the public be informed of the progress in the field. Such information is an essential part of our way of life and our form of Government; especially is it so in this field that so intimately affects our very existence.

Further, to be sure that it was clear that the power of the Commission to regulate the flow of information was confined essentially to matters having security significance (especially in light of the criminal sanctions authorized by the new law, which are discussed later) Sec. 146b. was added by the Joint Committee. This section denies the Commission any power to control or restrain the dissemination of information unless that power is granted by the Atomic Energy Act of 1954 or some other law.

Redefinition of What Is Restricted Data

A most important change in the substantive law is the re-writing of the standard for classification of information in the light of realistic appraisal of the current situation. The United States no longer is the sole possessor of atomic weapons. The Soviet Union has detonated what are believed to be both fission and fusion weapons. Britain has also tested atomic weapons. These other countries, then, also possess

special nuclear materials in some quantity. Other nations are also amassing information relating to nuclear processes without having detonated any weapon. It is therefore not in the best interests of this country that the control of information should be based on the premise that this country is the sole possessor of both special nuclear materials and of the knowledge of how to construct atomic weapons or nuclear reactors.

The former Act permitted the declassification of Restricted Data only when the Commission determined that it could be published without "adversely affecting" the common defense and security. This was a very strict limitation on the power of the Commission to publish technical information within the atomic energy field. It is most difficult indeed to certify that the publication of any information previously classified would not adversely affect the common defense and security.

The new Act shifts this basis for declassification to a more reasonable test. It requires the Commission to declassify that information "which can be published *without undue risk* to the common defense and security" (italics added). This recognizes that in making any decision on declassifying any Restricted Data the Commission is required to weigh the benefits to be gained from declassification against the harmful effects such action might have. This provision requires a judgment and a conscious evaluation of the good and bad results likely to result from the declassification.

One of the main criticisms of the atomic energy program, particularly by scientists and engineers, is that there is not free interchange of information. They believe that there are many good results that could come from having technical information available to all, in that it is always possible for some unexpected person to roll back the scientific frontier. Sometimes, they argue, the correlation of seemingly unrelated bits of technical information can have the most unusual and far-reaching effects. Having the technical information compartmentalized prohibits the desired "cross-fertilization" of different fields. On the other hand, the publication of one seemingly innocent piece of information can give any potential enemy a clue to a process he has not been able to understand or develop himself. These and other factors must, of course, enter into the Commission's determination of the degree of risk entailed in declassifying Restricted Data.

In the main, the new law provides the Commission with needed leeway in its decisions, and permits a more reasonable approach to the declassification problem under current conditions.

Positive Direction to Declassify Information

The new Act affirmatively directs the Commission to declassify information that can be published without undue risk to the common defense and security of the country. This positive direction is contained in the substantive portions of the Act relating to the control of information. Under the previous law, the authority to declassify was derived from a clause inserted in the definition of the term Restricted Data, which permitted, but did not direct, the AEC to declassify information.

This positive direction to the Commission also includes a mandate to examine any guides which the Commission might publish with respect to the classification of information, and to maintain a continuous review of the Restricted Data and of the guides to assure the free publication of any information no longer needed to be protected.

The former Act contained no positive instruction to the Commission to so review its classification policies and practices, and many have thought that the efforts of the Commission had been more toward the inclusion of material within the Restricted Data category, and less toward the removal from that category of information that did not properly require protection. Many felt that, under the former statutory provisions, the Commission had been able to enclose a large body of technical information within the boundaries of secrecy, without making commensurate efforts to determine how much information could properly be released, even though it might once have been properly safeguarded. Under the new law, there can now be no question of the Commission's authority to engage in this type of declassification activity, and indeed it is directed to do so.

This statutory direction and authority is of extreme importance in maintaining the proper kind of control over information that present conditions require to be controlled by the Government. The basic definition of Restricted Data is a broad and all-inclusive definition, and *all* information relating to the atomic energy field is automatically included within its broad and sweeping terms, or, as has been said, is "born classified." By giving the Commission the authority and positive direction to declassify information, proper balance is encouraged in its administration of the statutory provisions controlling information.

Simplification of Investigative Procedures

Coupled with the direct declassification powers, the Commission is given more flexible powers to determine the scope and extent of any background investigation required for the employment of persons in the atomic energy field. The prior Act required an extensive investigation into the character, association and loyalty of all persons associated with the program, if the person was going to receive any access to Restricted Data of any kind. The new Act still requires the Commission to have full investigations of those positions involving access to the more sensitive types of Restricted Data. However, it permits the Commission to determine the positions that will not provide access to sensitive information, and to establish standards for the scope and extent of the background investigations of such personnel.

This necessarily requires a double evaluation. It requires an evaluation of the types of Restricted Data to establish the sensitivity of the information, and it requires an evaluation of the scope of the positions to determine the extent to which there will be access to sensitive Restricted Data. Should, for example, the Commission find that most of the information respecting the nonmilitary uses of atomic energy is either declassifiable or not sensitive, it could establish a type of clearance standard that would require only the minimum of investigative procedures for persons working in that field. Thus the domestic development of the field by industry would be as little bound by restrictive clearance procedures as is consonant with the public interest. (This provision has been popularly referred to as the "gray area" provision.)

It should be noted, however, that it was not the desire of the Joint Committee or of the Congress that the Commission use the devices outlined previ-

ously to replace the full declassification procedures. Rather, it was hoped that even after the full declassification procedures had been followed, that there would be additional flexibility given to the Commission to deal with the less sensitive areas of classified information. And it is anticipated that placement of information in the "gray" category will be a step towards declassification of that information. Thus, both the declassification and the "scope and extent" clearance provisions are written in mandatory language in the new Act instead of in permissive language.

Streamlining of Relationships with Other Agencies

While the AEC's inter-agency relationships have only indirect effect upon the new industry, mention is made of them here to round out the approach taken in the new law to the problems of Restricted Data.

The Commission is given power to remove or exempt certain types of information from the category of Restricted Data in cooperation with the Department of Defense and the Central Intelligence Agency. Thus, the Commission and the Department of Defense must jointly agree that certain information, which relates solely to the military utilization of atomic weapons, can be published without unreasonable risk to the common defense and security before it can be declassified. Also, if the two agencies agree, other Restricted Data, relating solely to the military utilization of atomic weapons, can be removed from the Restricted Data category if it can be adequately protected as "defense information." Similar power to treat information relating to the atomic energy programs of other countries as "defense information" is given to the Commission and the Director of Central Intelligence jointly.

Perhaps the most important provision of this type is the one that for the first time permits, under carefully specified standards, participants in the atomic energy program to discuss mutual problems directly with participants in the military program. Under the old law persons within the atomic energy program who worked for an AEC contractor and who had to discuss problems with contractors in military programs (who had military clearance, but not AEC clearance) had to carry on the conversations through either a military officer who had an AEC clearance or through an AEC official. The new Act establishes the standards by which there can be face-to-face conversations on mutual problems between persons in the AEC program and in the military, with assurances that any Restricted Data will have adequate protection.

Granting Authority to AEC to Protect Restricted Data

With the ending of the Government monopoly in the atomic energy field, it is obvious that many more persons will gain access to Restricted Data. On the assumption that only that information that cannot be published without undue risk to the common defense and security was still to be included within the scope of Restricted Data, it was believed desirable that there be adequate and enforceable safeguards set up to protect information still within

Industrial Significance of the "Gray Area"

As pointed out in the accompanying article by Rep. Cole, it was intended that the new law would give AEC greater freedom in making information available. To find out what this might mean to industry and what is necessary to make it work, NUCLEONICS asked one of the country's top authorities on the subject, AEC's former director of classification, for his comments.

By J. G. BECKERLEY*

THE YEAR 1955 may be the year of the "gray area" for atomic industrial information. For in 1955 the Atomic Energy Commission will undoubtedly put into effect new secrecy regulations permitted by the Atomic Energy Act of 1954. As these regulations will be of substantial significance to those concerned with industrial applications of nuclear energy, the following comments may be of interest.

From an industrial point of view the most desirable course of action by the Commission would be:

1. To consider essentially all classified information on power reactor technology as restricted data of a lesser degree of importance to the common defense and security.

2. To reduce the clearance investigation for access to such information to a national agency file check or less.

3. To reduce the corresponding physical safeguards requirements—document storage, transfer, protection, etc. —to be consistent with the reduced clearance standards.

The file check referred to consists in determining whether there does or does not exist "derogatory information" on the individual in the files of the FBI, the military intelligence and other agencies. This process should be one taking ten days or less, where no derogatory information is found.

If these three steps are taken, the degree of effective industrial participation can be greatly increased. There will still be many impediments to the most efficient use of classified atomic energy technical information by industrial firms. However, it will be a great improvement if it is possible to clear in a few weeks large groups within a given industrial firm so that many can work on, think about, and discuss that to which only a few Q-cleared in the firm now have access. Such a reduction of intra-company barriers should greatly increase the rate of progress in nuclear power and related activities.

As far as intercompany relations are concerned, the benefits to be achieved under the new law will depend on the Commission's regulations for the dissemination of gray-area data. If Company A has to touch base with AEC every time it wishes to send data to or to discuss problems with Company B, the effectiveness of intercompany cooperation will be greatly curtailed. Considerable latitude must be given to each industrial firm in

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the Restricted Data category. Therefore the Commission, in Sec. 161.i. is given for the first time specific authority to issue regulations, carrying criminal sanctions for the protection of Restricted Data. In addition, each of the separate provisions permitting the issuance of a license to persons in the program who are not contractors or subcontractors of the Commission stipulate that the licenses are each subject to provisions for the protection of the common defense and security. All of these provisions are in addition to the general rule-making power given to the Commission under the revision of the prior Act made in 1953.

Closely akin to these powers is the ability of the Commission to protect Restricted Data in its own administrative proceedings by being permitted to establish regulations that will give adequate protection to the Restricted Data and yet fulfill the requirements of full public proceedings (where rules and regulations and licenses for independent licensees are involved), as closely as the paramount interests of the common defense and security will permit. Under the provisions of Section 181 of the new Act, these procedures must be established by regulation so as to minimize the possibility that any restriction on public proceedings will be arbitrarily or capriciously imposed for the sake of obtaining ends other than the protection of the common defense and security.

Tightening of Criminal Sanctions

The new Act continues in effect, and without substantive change, the provisions of the old Act establishing criminal penalties for the unlawful disclosure of information with intent to injure the United States or to give an advantage to a foreign country. However, it was felt that there should be some lesser punishment provided for the knowing disclosure of Restricted Data to any person not authorized to receive it regardless of intent. It must be remembered that what is included within the category of Restricted Data is only that information which the Commission, a responsible government agency, has determined cannot be published without undue risk to the common defense and security. Any disclosure of the information would constitute a publication. Therefore, regardless of the lack of intent of the person to injure the United States or to give an advantage to a foreign country, the unlawful and knowing disclosure of Restricted Data by persons who received it in connection with their work in the atomic energy field was made subject to a fine of $2,500.

Conclusion

In this article I have attempted to outline the basic purposes of the new Atomic Energy Act of 1954, and the basic changes incorporated to bring the information control policies and programs of the Government into reasonable accord with a realistic appraisal of changing security requirements. I venture to state that if the new law contained no other progressive changes than those in the field of information control, it would still be an extremely worthwhile legislative revision; happily, it is not so limited, as discussed in forthcoming articles.

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deciding the secondary dissemination of the classified (gray area) information it has received. If Company A has good reason to believe Company B can help in a classified nuclear power problem, then it must be possible for Company A personnel to get together with Company B personnel (gray-area cleared) on short notice and with no bureaucratic limitations on the technical scope of the discussion—i.e., the technical scope must be determined by Company A personnel.

With respect to the possibilities of new companies participating, the principal effect of the new legislation should be to reduce the obstacles to their exploring in detail whether they *want* to get into any specific phase of the nuclear power development program. A rapid clearance procedure should make it possible for a new company (i.e., one which has not previously participated in classified work) to permit some of its engineers and management to explore in detail the pros and cons of company participation. The present burdensome (in time and money) clearance process plus the rigidity of AEC physical security regulations are often too great a hurdle for such concerns. The new law should make it possible to get far enough "inside" the project (and painlessly enough) to make a technically sound assessment of the value of participation.

Will the gray area work? The Atomic Energy Act of 1954, just as its predecessor, puts all the responsibility and authority in the Commission's hands. Success or failure depends on the Commission's actions. If AEC adopts security regulations that are only a shade less stringent than at present, the new law's security provisions are bound to fail to stimulate an increase in the rate of nuclear power development. If AEC adopts technically unsound limitations on the scope of the less sensitive gray-area information, the effectiveness of industrial participation will be limited.

Moreover, if the rate of declassification of technical information is reduced by relegating *declassifiable* items to the gray area, the rate of progress in nuclear power development will be adversely affected. Unclassified data are essential for use in university and engineering school training as well as for the stimulation of new ideas through public technical society conferences and meetings, as well as through publication of technical journals.

The success of any gray-area arrangement will require a real change in attitude on the part of the Commission. The Commission will have to bolster up its courage and handle a large body of technical information on a much less secure basis than has been customary. It will have to clear many persons without the assurance of FBI or Civil Service Commission investigation files.

The Commission may be exposed to public and Congressional criticism. Gray-area information may leak or gray-area cleared persons may turn out to be questionable security-wise. Such happenings are politically vulnerable, particularly among the still large number of persons who cherish the myth of THE SECRET.

Will AEC have the courage to risk becoming a target for irresponsible political attack? Will AEC take the bold steps permitted, but not required, by the new Act and encourage broad dissemination with minimal security requirements of gray-area restricted data concerning industrial applications of atomic energy? Or will Commission regulations make the "gray" just an imperceptible shade different from the present "black"?

These questions will be answered in 1955. The answers will have an important bearing on our national nuclear energy development.

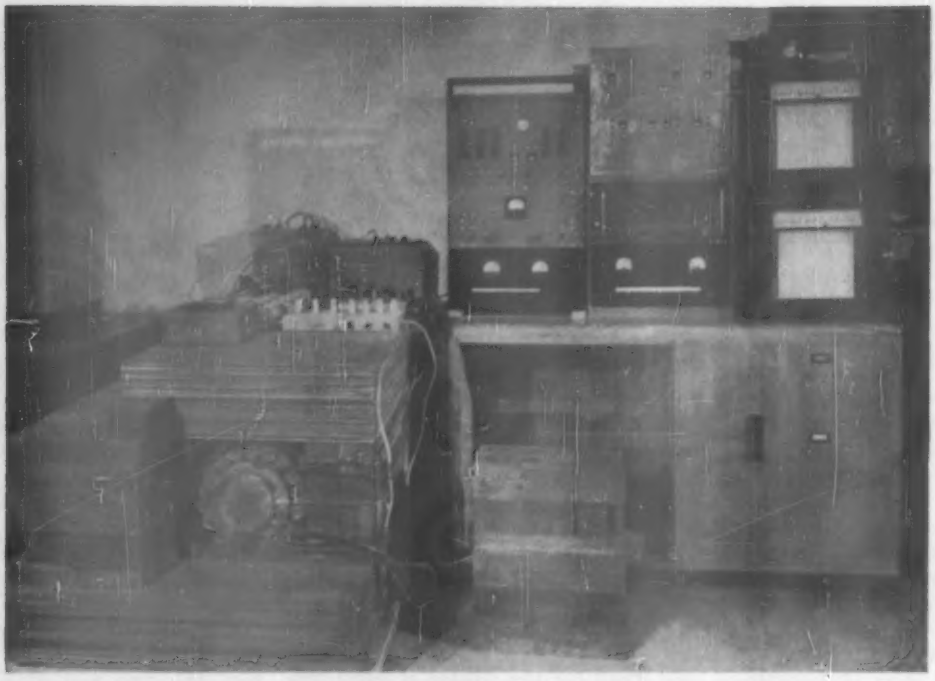

FIG. 1. Over-all view of counting system with front of iron shield removed to show counters

Radiocarbon Dating System

Dating range has been extended to 45,000 years and accuracy of "living-carbon" assay increased to 0.3% by carefully instrumented system centered on a 7.7-liter proportional counter filled with up to 3 atmospheres of pure CO_2

By G. J. FERGUSSON
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AN IMPROVED METHOD for radiocarbon dating has been developed to supplant the solid-sample method (*1*) previously used here (*2, 3*). The system (Fig. 1) centers around a well-shielded 7.7-liter proportional counter filled with up to 3 atmospheres of especially purified CO_2. The output pulse heights are analyzed electronically. In addition, pulses are sorted according to whether or not they are in coincidence with a surrounding ring of G-M counters. This identifies most of cosmic-ray background.

For "living" carbon the counting rate is 37.5 cpm above a background of 9.8 cpm for a counter-filling pressure of 1 atm and 103 cpm above 14 cpm background for a filling pressure of 3 atmospheres. For most problems a filling pressure of 1 atmosphere appears to offer the best compromise between accuracy and man-hours of work per sample. When increased accuracy is desired a 3-atmosphere filling is used.

The maximum age that can be measured is arbitrarily defined here as the age for which the net sample count is equal to four times its statistical standard deviation. This definition has also been used by several other workers (*4*). For a 1-day count on sample and on background the maximum age is 35,000 yr for 1 atmosphere and 42,000 yr for 3 atmospheres filling pressure. For a 2-day count on sample and on background with 3-atmosphere filling, maximum age is 45,000 yr.

Apparatus in General

Carbon in the sample to be dated is converted to CO_2, which is then purified according to a procedure developed by

Rafter.* The purification procedure is basically similar to that of De Vries and Barendsen (*5*). It involves appropriate washings, absorption on lime at 700–750° C, and then re-evolution at a higher temperature (800–900° C). Electronegative impurities are also absorbed on the lime but are not re-evolved even at 1,000° C. The purified CO_2 is then passed into the proportional counter.

A low background counting rate is achieved by extensive gamma-ray shielding. Surrounding the proportional counter with a ring of anticoincidence Geiger-Müller counters (Fig. 2) identifies counts due to cosmic-ray mesons. The unshielded background of the proportional counter is approximately 2,000 cpm while its background when operating in the equipment is only 10–14 cpm. This background counting rate is checked periodically by filling the counter with CO_2 prepared from coal (more than 50,000 yr old).

Pulses from the counter are linearly amplified and then electronically sorted into four groups depending on their amplitude, as shown in Fig. 3. The pulses in each of these groups are then sorted into two groups, depending on whether they are or are not in coincidence with a pulse from the ring of G-M counters; thus the sorter has eight outputs. The energy distribution of coincidence pulses is shown by the number of counts in the four coincidence channels, and the energy distribution of anticoincidence pulses is displayed in the four anticoincidence channels.

Counter Construction

The proportional counter, constructed from 5-in.-o.d. copper tubing, is 28 in. long. Previous experience had shown that, of the readily available materials suitable for counter construction, copper had the lowest proportion of radioactive impurities.

The anode is 4-mil tungsten wire with a sensitive length of 21¾ in. At one end of the counter the anode connection is brought out through a Pyrex insulator and is provided with a guard ring. At the other end, the anode has a long glass insulator, and no guard ring is provided. The ends of the counter are made approximately hemispherical to prevent them from flexing

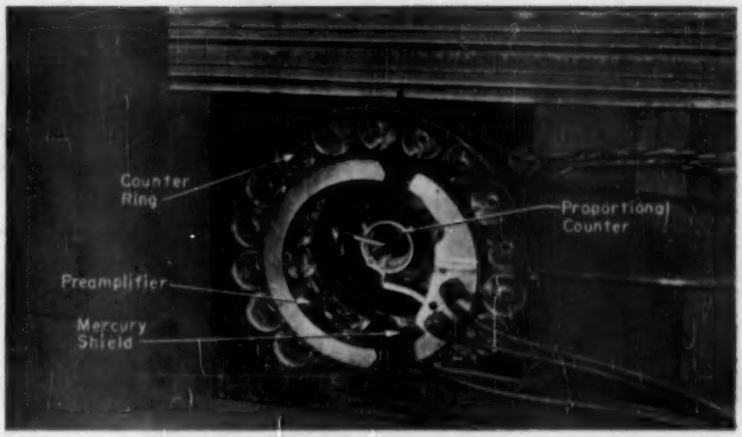

FIG. 2. Counter ring surrounds proportional counter, visible with cover removed. High voltage for proportional counter is supplied from banks of stable 67½-v batteries to anode and cathode in equal + and − parts respectively. Thus only two end insulators have to stand full counter voltage (up to 10,000 v); maximum voltage elsewhere is ½ that. Small variations in voltage or gain are corrected by changing cathode voltage. Preamplifiers shown use 4 6AK5's in a ring-of-3 feedback-stabilized amplifier with cathode-follower output; gain is 40. Heaters are d-c powered in series; plate supplies are heavily filtered. Locating preamplifier within γ-ray shield results in short counter leads and good electrical shielding

when the pressure is changed and to reduce dead space. The sensitive volume is 80% of the 7.7-l total.

Filling the Counter

The proportional counter remains permanently in position in the gamma-ray shield. A glass pipeline connects it to the filling system next door.

The Pyrex filling system is evacuated by a mercury diffusion pump backed by a two-stage rotary pump. The pressure in the system can be reduced quickly to 10^{-4} mm Hg. Adequate "condensation traps" are provided to allow for experimentation with final purification and filling procedures. The system is also arranged so that the most time-consuming operations, distillation of CO_2 and pumping the counter, can proceed simultaneously. Provision is also made for storing the sample being removed from the counter.

After chemical purification the CO_2

Possible Dating Methods—Why CO_2?

This table indicates some of the comparisons involved in our choice of proportional counting of CO_2 as the basis of our radiocarbon dating system. It appeared to offer the best compromise of conflicting requirements.

Method	*C^{14} detection efficiency (%)*	*Residual background*	*Possibility of radioactive contamination*	*Man-hours per sample*	*I.F.†*
Solid-sample (*1*)	5		High, inorganic preps, solid	High, 3 × CO_2	Yes
CO_2 gas proportional	Up to 100	Relatively high; one C per molecule means large counter	Low, only gaseous contaminants, i.e., Rn	Lowest; convert C to CO_2 first in all methods	No*
Hydrocarbon gas proportional (*13, 14*)	Up to 100	Better than CO_2	Low, but more reagents than CO_2	High	Yes
Liquid scintillation (*15*)	Up to 100	Best, small volume	Medium; organic preps, liquid	High	Yes

† Possibility of isotopic fractionation. *100% transfer of CO_2.

*T. A. Rafter, *New Zealand J. Sci. Technol.* (in press).

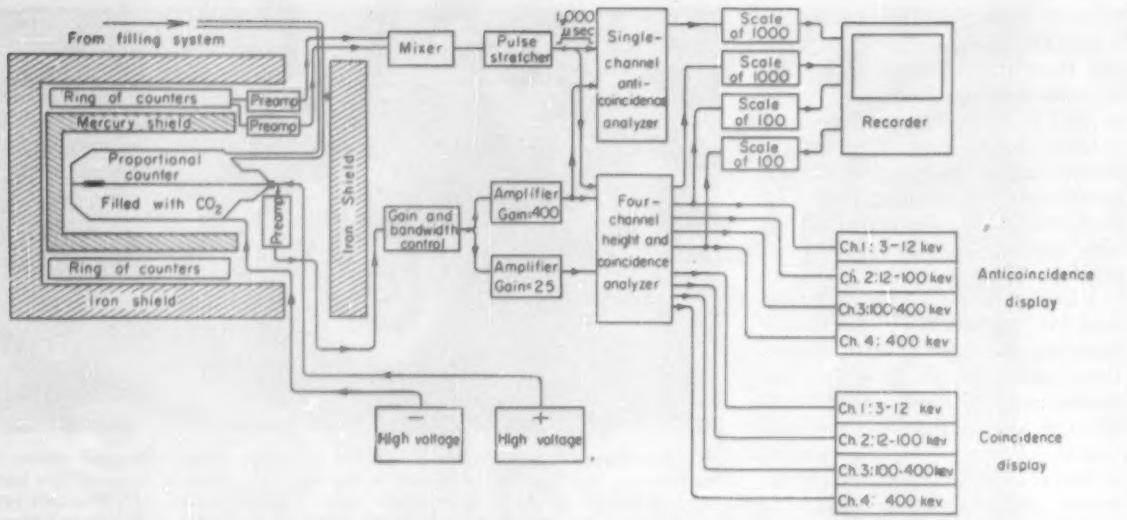

FIG. 3. Circuitry outside of shield begins with gain control, normally set at −12 db. Bandwidth control, normally a 40-μsec differentiator, is to control frequency response for optimum signal-to-noise. Parallel main amplifiers are ring-of-3 feedback-stabilized; ratio of their gains is accurately set at 16:1 by control in lower-gain amplifier. Four-channel analyzer has four discriminators with cancelling circuits arranged so that only highest discriminator triggered records. Two lower-level discriminators are fed by high-grain amplifier, higher two by low-gain amplifier. Energy loss in counter corresponding to each channel is shown. The analyzer also sorts pulses according to whether or not they are in coincidence with a pulse from the surrounding counter ring. Coincidence events are largely due to cosmic-ray mesons. Pulse stretcher in ring output insures coincidence pulse is present even if meson passes through G-M counter recovery. Parallel single-channel analyzer checks four-channel anticoincidence count

sample is removed from the chemical system as "dry ice," having been frozen with liquid oxygen. It is contained in a 100-cm³ flask provided with a stopcock so that it can be removed from the chemical-purification system and joined to the counter-filling system without admission of air. At this stage the sample still contains traces of air trapped in the frozen CO_2 and traces of water, both of which would upset its counting characteristics.

On the counter-filling system the CO_2 is distilled from one condensation trap to another and then pumped. The process is repeated until the amount of gases, noncondensable in liquid oxygen (mainly air), is less than 0.1 ppm of the CO_2. One distillation is usually sufficient.

The frozen CO_2 is now allowed to expand and pass into the counter through a P_2O_5 drying tube that also acts as an efficient dust filter. It is essential that drying be carried out last; if drying precedes distillation, sufficient water vapor will be outgassed from the glass to affect counting characteristics.

The counter is filled to the desired pressure (78–230 cm Hg) when the counter temperature is 18° C as measured by a resistance thermometer with an accuracy of ¼° C. At any other counter temperature the filling pressure is changed so that the mass of gas in the counter is constant from one filling to the next to 1 part in 1,000. The working voltage of the proportional counter as a function of filling pressure for a gas gain of 2,000 is shown in Fig. 4.

Shield and Counter Ring

To prevent gamma rays from reaching the counter, an 8-in.-thick iron shield is provided. This shield is built of mild steel plate and machined cast-iron blocks, the space provided for the proportional counter and ring of meson counters being 14 × 14 × 36 in. A layer of mercury 1 in. thick surrounds the counter to provide additional shielding and also absorb some of the gamma rays from radioactive contaminants in the iron. The arrangement of these components is shown in Figs. 1–3.

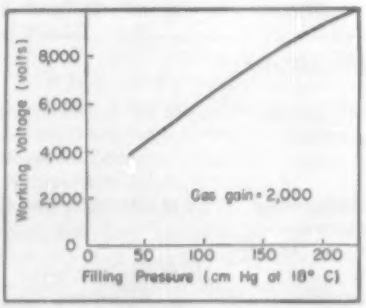

FIG. 4. Working voltage of the proportional counter as a function of CO_2 filling pressure for a gas gain of 2,000

Between the mercury shield and the iron shield is the ring of 18 G-M counters, each 2 in. o.d. and 35 in. long. The ring of counters is divided horizontally into two segments. This division enables a faulty counter to be detected quickly by a comparison of the counting rates of the segments. Each segment has its own preamplifier that provides a 900-μsec quenching pulse. Deadtime of the counters is 600 μsec so that 900 μsec is about the minimum quenching-pulse duration that can be used.

The total counting rate of the ring of counters is 2,600 cpm, so a 4% loss of anticoincidence counting rate occurs due to the total deadtime of the ring of counters. The size of the ring of counters is thus as large as is practicable unless the counting rate were to be reduced by operating underground to reduce the meson flux.

Associated Electronics

The counter voltage supply, amplifiers, and pulse-height analyzers are described in Figs. 2 and 3.

The output of the pulse-height analy-

zer is counted as follows: each anticoincidence channel output is counted by a scale-of-4 and a mechanical register, each coincidence channel by a scale-of-10 and a register.

Recording equipment provides information about the progress of the counting during overnight operation. When the scale-of-1,000 that counts the anticoincidence output of the single-channel analyzer reaches full-count it resets. This actuates a pulse-forming circuit that feeds a signal to a single-pen millivolt recorder and thus marks the recorder paper. The paper moves at a constant 3 in./hr, so the counting rate at any time can be calculated from the spacing between marks.

Similarly, the counting rates of the lowest and the highest anticoincidence channels are recorded using scales-of-100. The pulses in all four anticoincidence channels are added together and recorded also, using a scale-of-1,000.

Until more recording equipment arrives only these most important counting rates can be recorded.

Temporary faults that affect the counting rates will be apparent from the record. The appropriate period can be deleted so that an erroneous answer is not obtained for the counting rate.

It is worth noting the high standard of performance demanded of the electronic equipment and the proportional counter if the correct counting rate is to be obtained. The statistical accuracy possible from this equipment is approximately 0.1 cpm, i.e., 6 cph.

The voltage applied to the proportional counter is 10,000 volts for a 2-atmosphere filling. A count will be registered for all pulses greater than 2 mv at the anode of the counter. A small rapid change in counter anode voltage, due to corona discharge or current leakage across the insulators, can cause spurious pulses. To avoid this, counter voltage must not change more than 1 part in 5,000,000 per 100 μsec. If such pulses do occur the counting rate in channel 1 will change, the other channels not being affected. The counting rates from the other channels can thus be used for calculating sample activity for this particular run.

Spurious anticoincidence pulses can also result from a change in efficiency of the ring counters and pulse analyzer. The coincidence counting rate is 600 cpm, so that 0.02% change in ring-counter or pulse-analyzer efficiency will

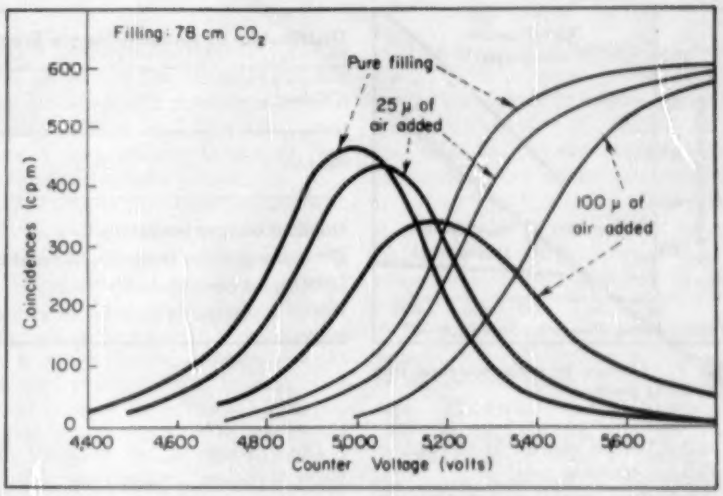

FIG. 5. Curves used to check for electronegative impurities give coincidence counts in channel 1 (heavier lines) and channels 2 + 3 + 4 (lighter lines) as a function of counter voltage

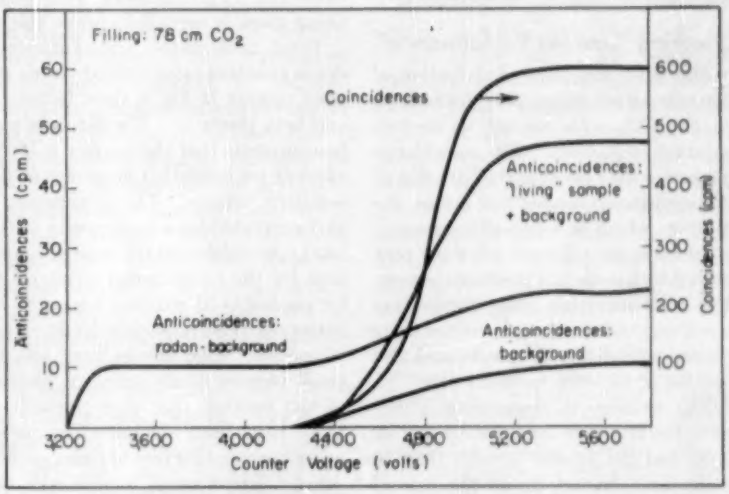

FIG. 6. Total coincidence and anticoincidence counting rates as a function of proportional-counter voltage for a 78-cm CO_2 filling. Flat plateaus suggest low electron attachment

CO_2 as a Counter Gas

The results in our laboratory show that previous difficulties with CO_2 as a counter gas were due to electronegative impurities and not to the CO_2 itself. These electronegative impurities were separated from the CO_2 but have not yet been identified. For reliable proportional counting, the loss of electrons due to electronegative impurities should be less than a few per cent. To keep the electron loss less than 1%, the concentration of O_2 must be less than 1 in 10^8, the concentration of Cl_2 must be less than 1 in 10^9.

When we first considered using CO_2 we were not very optimistic in view of the measurements of English and Hanna (11). These workers were unable to get saturation even with the purest CO_2 commercially available, indicating that electron attachment was taking place. Freedman and Anderson (12) had used a CO_2-filled proportional counter for biological applications, but the plateau slope of 10% again indicated electron attachment. De Vries and Barendsen (5) have applied CO_2 counting to radiocarbon dating, using a small counter.

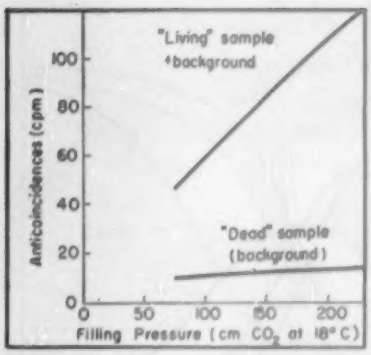

FIG. 7. Change in anticoincidence rate with filling pressure

Distribution of Anticoincidence Events

Channel	1	2	3	4
Source	*(% of total counts in each channel)*			
Residual counter background	14	61	22	3
C^{14} disintegrations from CO_2 in counter	13	75	12	0
CO^{60} source outside shield	9	62	29	0
Radon in counter in equilibrium with daughters	6	32	18	44

cause 0.12-cpm change in the anticoincidence counting rate.

Thus very careful design and construction of counting equipment is essential to achieve the reliable counting required for this dating method.

Checking Counter Performance

The pulse amplitude distribution of the coincidence pulses provides a check on the CO_2 with respect to electronegative impurities. The coincidence pulses are used because they are due to the cosmic-ray meson flux across the counter, which is essentially constant, apart from variations of a few per cent caused by barometric pressure changes. The anticoincidence pulse distribution is not very suitable because of the large change with different samples and also because of its lower counting rate.

The number of coincidence pulses from the amplifier between 7.5 and 30 volts and the number greater than 30 volts (i.e., channel 1 and the sum of channels 2, 3, and 4) are plotted versus counter voltage in Fig. 5. A small amount of electronegative gas displaces these curves as shown. The counter voltage at which a pair of curves cross can be quickly checked, since both curves are steep there. A quick and accurate check of CO_2 purity is thus possible.

The counter voltage at the cross point will repeat from one filling to the next within 5 volts in 5,500 for a 78-cm filling. If 1% of the electrons are being lost due to electron attachment, the cross-over point will occur at a gas gain 1% greater than for no loss. A 1% change in gas-gain corresponds to a counter-voltage change of 2½ volts. Thus from one filling to the next the change in electron loss due to electron attachment is less than 2%.

Observations of the shape of the curve of channel 1 with change of filling pressure suggests that not only is the change in electron loss less than 2%, but that the actual electron loss is less than 2%. Further work with other filling gases is needed to prove this.

Total coincidence and anticoincidence counting rates plotted versus applied voltage in Fig. 6 show flat alpha and beta plateaus. The flat beta plateau suggests that the counter is 100% efficient for ionization occurring in the sensitive volume. This conclusion is also supported by a comparison of the total meson rate and the cross sectional area for the proportional counter and for smaller G-M counters known to be better than 99.8% efficient for detection of mesons. End effects must also be small because of the excellent plateau of the counter, but as a precaution, these have been eliminated by measuring the counting rate of living carbon using different anode lengths with the same style of anode terminations.

The choice of energy range covered by each channel was made so that the lower limit of the lowest channel falls on the beta plateau while the highest channel includes only those pulses due to alpha rays. The boundaries of channel 2 were chosen so that approximately 75% of the C^{14} disintegrations fall in this band.

The change in anticoincidence counting rate with change of filling pressure is shown in Fig. 7 for a "dead"-carbon-sample filling and for a "living"-carbon-sample filling.

Background

Some radon is always present in each filling. This radon arises from a trace of radium in the lime employed in the final step of the chemical purification. The amount present is proportional to the time the CO_2 is left absorbed on the lime. The pulses due to alpha rays from radon and its daughter products are recorded in channel 4. However, beta rays from daughters of radon produce pulses in channels 1, 2 and 3. The number of these pulses bear a fixed relation to the number of pulses in channel 4, and a correction can be applied.

The table on this page shows the distribution of anticoincidence events in the four channels for several sources of radioactivity, measured for normal operating conditions.

The remaining background counting rate of the proportional counter is the sum of four components due to counter contamination, mesons not detected by the counter ring, gamma rays from radioactive contamination of the shield, and gamma rays associated with the cosmic rays. Previously, when G-M counters have been used, it has not been possible to investigate the relative contributions of these four components. The use of a proportional counter, combined with different filling pressures, now enables the following information to be obtained.

1. **Alpha and beta rays from radioactive contamination of counter materials.** An alpha counting rate of 0.33 cpm is obtained when the counter is filled with radon-free CO_2. The source of this alpha rate is almost certainly traces of the elements of the U and Th series in the copper wall of the counter. Thus, beta rays will also be present, and owing to their greater range, their contribution to the background counting rate will be approximately five times the alpha counting rate. Thus the counting rate due to radioactive impurities in the copper of the counter will be approximately 2 cpm. The

area of the cathode surface of the sensitive volume of the counter is 2,100 cm², so that the alpha rate is 1.6×10^{-4}/cm²/min, which agrees closely with the lowest figures reported by Bearden (*6*). It is therefore unlikely that this background component could be decreased appreciably by trying to obtain radioactively purer material for the construction of the counter.

2. Cosmic-ray mesons not detected by the ring of counters. Calculations based on the geometrical relationship of the proportional counter and the surrounding ring of counters indicate that approximately 2 cpm of the background counting rate will be due to mesons not detected by the ring of counters. With more counters in the ring this component could be eliminated at the expense of a slight increase in equipment complexity.

3. Gamma rays from radioactive contaminants in the gamma-ray shield. It has been noted (Fig. 7) that the background counting rate increases with filling pressure for "dead" CO_2—being 10, 12, and 14 cpm for 1, 2, and 3 atmospheres respectively. This could be due either to a radioactive contaminant in the gas or to an increase in efficiency of detection of gamma rays. The relative efficiency of detection of a strong gamma ray source outside the gamma ray shield was therefore measured as a function of pressure of CO_2 in the counter. An increase of 30%/atmosphere was observed.

The 2 cpm due to counter contaminants and the 2 cpm due to undetected mesons will be independent of pressure. The variation of the remainder of the background counting rate with pressure is then 6, 8, and 10 cpm for 1, 2, and 3 atmospheres respectively. As this agrees with the change of gamma-ray efficiency with pressure it may be concluded that, at 1 atm filling pressure, 6 cpm are due to gamma rays passing through the counter.

The gamma-ray shield provides 8 in. of iron and 1 in. of mercury as shielding around the counter. The background counting rate at 1 atm filling pressure is reduced from 14 to 10 cpm by the addition of the mercury, so a reduction of 4 cpm is due to absorption in the mercury of γ rays from the iron. One in. of mercury will have a shielding factor of approximately 6, so less than 1 cpm of the background will be due to γ rays from the iron.

There are two reasons for believing that the gamma rays from radioactive contaminants in the mercury cause only a small (<5%) contribution to the background counting rate. Firstly, Kulp and Tryon, in their experiments with a mercury shield (*7*), obtained only a small improvement between the use of commercial-grade mercury and triply distilled mercury. Secondly, the 400 lb of mercury used in our shield was obtained in batches from several sources of supply. Batches were compared in lots of 50 lb for radioactive contamination in a low-background Geiger-counter arrangement. No difference between the various batches was detectable.

4. Gamma rays associated with the cosmic-ray flux passing through the gamma-ray shield. The background counting rate appears to depend on barometric pressure, but unfortunately statistical variations of the counting rate and the small percentage change of barometric pressure prevent this correlation from being established accurately. The pressure coefficient observed for mesons (coincidence counts from counter) is −2%/cm Hg. For the total background counting rate (anti-coincidence counts from counter) it is (-3 ± 1)%/cm Hg. Therefore, it is reasonable to assume that the remaining 5 cpm of background due to gamma rays is associated with cosmic rays.

The amount of radon and thoron present in the atmosphere is known to be dependent on the barometric pressure. The possibility of this variation affecting the counting rate has been eliminated by continuous flushing of the space between the proportional counter and the mercury shield with nitrogen gas.

If the preceding reasoning is correct, a considerable decrease in the background counting rate should be obtained by setting up the equipment underground so as to reduce the components (2 and 4) associated with cosmic rays. At 100 ft underground, background components associated with cosmic rays would be reduced sufficiently to be negligible compared to shield and counter contaminant background. The background counting rate of the equipment would then be approximately 3 cpm.

* * *

The author wishes to acknowledge the collaboration of T. A. Rafter who developed the chemical procedures for burning the samples and purifying the CO_2, and of W. McCabe for his careful preparation of the numerous samples that have been necessary during developmental work. Construction of nearly all electronic equipment has been by K. A. Bargh whose attention to detail has contributed to its reliability. This paper is published with permission of the Director of the Dominion Physical Laboratory.

Contemporary Assay Results

The CO_2-filled-proportional-counter method for radiocarbon dating will help analyze the fine structure of the contemporary C^{14} assay. Using only 12 gm of carbon, an accuracy of 0.3% in C^{14} content is possible.

Already the specific activity of natural radiocarbon in living wood samples has been measured as 12.5 ± 0.2 dpm/gm. This figure is considerably lower than the currently accepted 15.3 dpm/gm (1) but agrees with the 12.9 ± 0.2 dpm/gm obtained by others using scintillation counting of organic compounds (8). Various species of New Zealand woods tested agree within ±½% of the mean value.

The specific activity of natural radiocarbon in the carbonate of shellfish has been found to be (5 ± 1)% greater than for their flesh (two samples only). This is in close agreement with the theoretical figure of 6% and lies approximately in the middle of the range of 0–10% obtained by others (1, 9, 10). These results will be published in greater detail at a later date.

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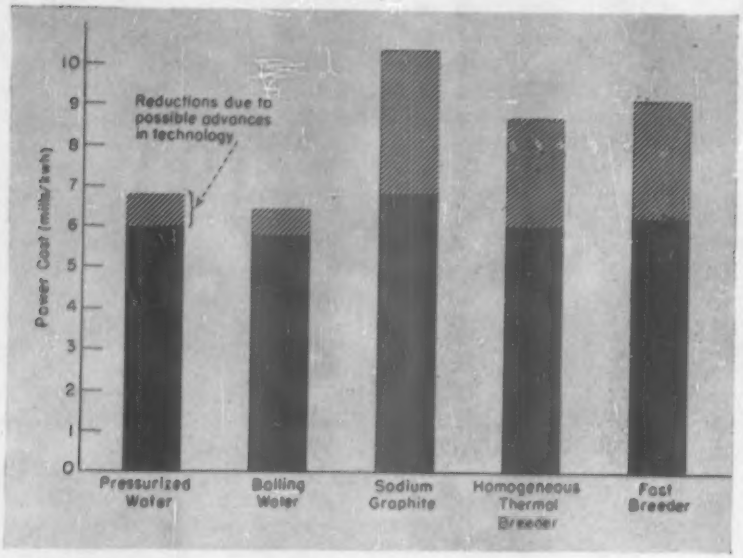

FIG. 1. Estimated power costs and possible cost reductions in large-scale nuclear power plants using various reactor types

Reducing Nuclear Power Costs

Cost factors in obtaining power from homogeneous thermal breeder reactors are compared with similar factors for other reactors and coal plants to determine conditions and reductions necessary to achieve nuclear power costs competitive with coal-produced power

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NUCLEAR POWER ECONOMICS studies show two very important things: 1, if foreseeable advances in reactor technology can be realized, electricity from uranium unquestionably will compete with electricity from coal in a large number of reactor systems; and 2, paper studies alone cannot differentiate between reactor types—design, construction, and operation are needed to adequately define the best approach to large-scale industrial nuclear power. Such studies pointed the way toward

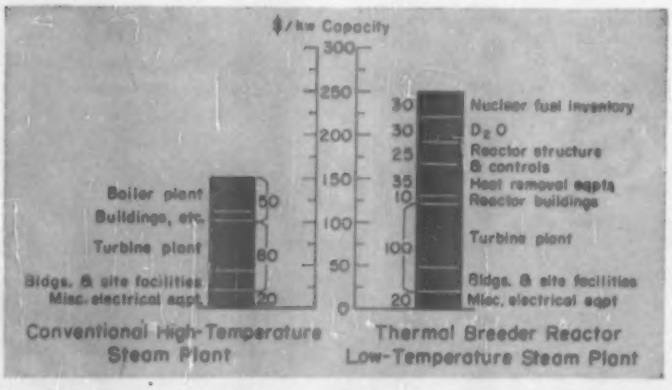

FIG. 2. Comparison of investment required in nuclear and coal-fired 200-Mw power plant that produce power of equal total cost

* Operated by Carbide and Carbon Chemicals Co. for the U. S. Atomic Energy Commission.

the Atomic Energy Commission's vigorous five-year power-reactor development program (*1*, *2*) and will assist in defining areas most needing development effort.

By putting reactor designs on a comparable basis by adjusting nontechnical factors, but maintaining original technology and design features, the cost comparison shown in Fig. 1 is obtained for the reactor designs being developed under AEC's program (*3*). Possible cost reductions due to a reasonably successful development program are shown also. Remembering that the data include many arbitrary assumptions, it seems that nuclear power will compete with power from coal at \$6–7/ton. If these results can be accepted at face value, it is evident that AEC's \$200-million program is well justified.

To simplify cost analysis in checking the figures, a specific type of reactor, the homogeneous thermal breeder, will be used as an example. A comparison of a breakdown of capital costs in such a nuclear plant and in a coal-fired plant is shown in Fig. 2. The capital costs of heavy water and nuclear fuels are shown separately since the accounting procedures for these items may be unique. Figure 3 compares corresponding power costs.

Cost Considerations

It is interesting to see how nontechnical factors as well as technical ones cause nuclear power costs to deviate from the base case. The range of values normally encountered in considering these factors is shown in the table. The variations are not extreme and represent data used in actual cost studies.

Nontechnical factors. In regard to special safety precautions, without more experience one cannot be truly realistic concerning what is needed to insure that no accidents occur in a nuclear power plant. The numbers shown assume arbitrarily that safety precautions may add about \$1-million to the cost of a large plant, or about \$10/kw of installed electrical capacity.

Exclusion-area requirements are closely allied to the question of safety. If the formula of the advisory committee on reactor safeguards is adhered to (*4*), this amounts to about 1 acre/kw of installed electrical capacity. Depending on the cost of the land, the total amount can be as much as \$400/kw capacity; the \$100/kw figure is probably low. However, recent studies indicate that exclusion areas can be reduced considerably (*5*). The other nontechnical factors are more or less self-explanatory.

Technical factors. For the homogeneous reactor plant considered, heat is removed by circulating fuel solution through the reactor and then to a heat exchanger or steam generator. The design of this fuel circulating system will have an important bearing on the amount of heavy water and enriched fuel held up in the system, and thus on the fixed charges due to these materials. The ranges given represent those encountered in typical designs.

On the question of thermal efficiency, much has been said concerning the desirability of operating the reactor at high temperatures to increase the efficiency of converting heat into electricity. Although high thermal efficiencies lower fuel costs, in a nuclear plant having low fuel costs the most important effect is on the investment in power generating equipment. Figure 4 shows that investment in a turbogenerator plant associated with a water-cooled reactor is not greatly different from that for a sodium-cooled reactor or for a conventional high-pressure steam plant.

Fuel Costs

Costs related to fuel in a nuclear plant are a function of many interrelated variables, such as the ore cost, fuel type, enrichment, fabrication costs, burnup, cost of processing to remove neutron poisons and to recover unburned fissionable material, the production and net value of fissionable material recovered from fertile material in the reactor, and, finally, thermal efficiency. Without attempting to show how these factors enter into actual fuel cost calculations, let us consider simply the average cost in typical cases for reactors fueled with natural uranium, with slightly enriched uranium containing about 1–2% U^{235}, and in reactors fueled with highly enriched uranium or plutonium.

Figure 5 shows fuel costs in natural-uranium-fueled reactors as a function of burnup, expressed as megawatt days per ton of uranium. Where plutonium is recovered and sold at \$20/gm, burnups of about 5,000 Mwd/ton are sufficient to get fuel cost low enough to be of interest or equivalent to that shown in the base case. In a 1,000-Mw reactor containing 100 tons of uranium, a burnup of 5,000 Mwd/ton means each fuel loading would last about 1¼ years (equal to 0.2 ton uranium per day).

Figure 6 shows comparable data for reactors fueled with slightly enriched uranium. In this case, burnups of the order of 15,000 Mwd/ton are necessary for economic power production.

Finally, in the case of reactors fueled with highly enriched uranium or plutonium, or, in other words, the breeder reactors, the important factor is not burnup but the cost of processing and recovering the enriched fuel. Figure 7 shows fuel costs in breeder reactors plotted as a function of processing costs for various values of the conversion ratio, which is defined as grams of fissionable material produced in fertile material in the blanket of a

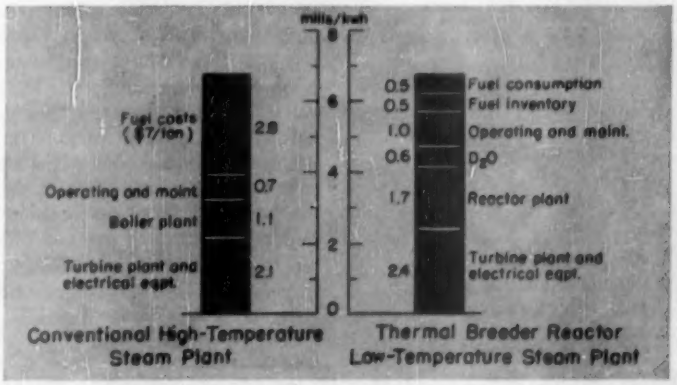

FIG. 3. Comparison of power cost factors in nuclear and coal-fired 200-Mw power plants that produce power of equal total cost

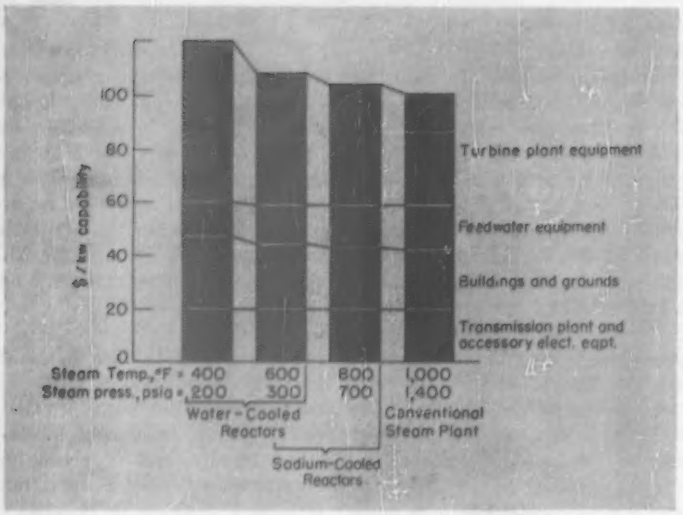

FIG. 4. How steam conditions affect turbogenerator plant investment

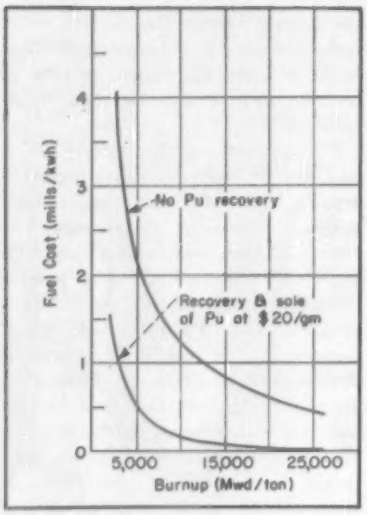

FIG. 5. Fuel costs for natural-uranium reactors. Basis: U metal at $20/lb, 25% thermal efficiency, credit for unburned U^{235}

reactor per gram of fuel burned in the core. These curves show that even with reasonably high conversion ratios, processing costs less than $2/gm are necessary to achieve fuel costs low enough to be of interest.

There are two processing cycles to consider in breeder reactors. Fission products must be removed from the fuel. If the fuel is U^{235} or U^{233} solution, this can be done rather easily by a continuous process such as centrifugation or adsorption. However, the fertile material, thorium, is in solid form as thorium oxide slurry or even thorium rods. As far as we know, there is no aqueous thorium solution except the nitrate, and this is not satisfactory for a breeder reactor. Thus, the solid thorium particles must be dissolved and put through a conventional solvent extraction process to remove the U^{233} formed and to recover the thorium. The slurry then has to be remanufactured or refabricated from the purified thorium salt.

Cost Factors in Thermal Breeder Reactor Power Plants

Factors	*Assumed range of variables*
Nontechnical	
Special safety precautions	$0–10/kw electricity
Exclusion area requirements	0–1 acre/kw ≈ $100/kw elect.
Fixed charges for reactor plant amortization	3–10% annually
Government-controlled materials	
Natural-uranium metal	$20–40/lb
Heavy water	$20–40/lb
Rental charges on nuclear fuels	5–12% annually
Load factor	90–70%
Technical	
Specific power (heat removal)	5–12 kw heat/gm enriched fuel 8–25 kw heat/liter D_2O
Reactor plant costs (excl. fuel)	$60–125/kw electricity
Turbogenerator plant costs	$120–150/kw electricity
Thermal efficiency	20–30%
Fuel costs (Burnup, reprocessing and recovery of fissionable and fertile material)	See curves

Variation in Power Costs

Taking all the previously mentioned factors into consideration, Fig. 8 compares the possible maximum and minimum power costs with the base case, assuming that only nontechnical factors (those independent of the design of the reactor) vary. It is evident that depending on the particular set of assumptions chosen, estimated power costs can vary by more than two. Combining these factors with the technical factors, which depend on the particular reactor design, results in even greater differences as shown in Fig. 9. It must be remembered that this large variation is due merely to the combination of normal design variables and reasonable accounting procedures, and is not a result of extreme assumptions. Thus, one has a right to ask whether the nuclear power costs usually reported in the literature are reasonable. The answer to this is that they are reasonable only for the given set of assumptions and that it is possible to select a different set, though equally reasonable, that give estimated costs that may not be competitive with power from coal.

Conclusions

The most important aspect of cost studies is that they enable one to

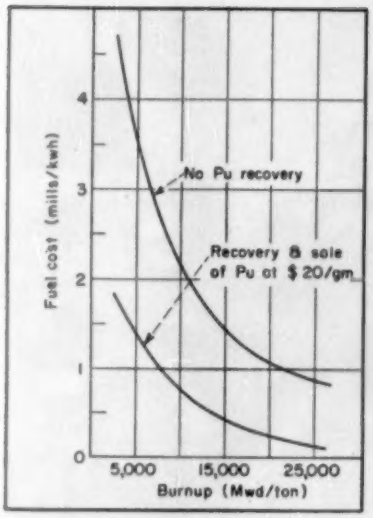

FIG. 6. Fuel costs for slightly enriched (1–2% U^{235}) U reactors. Basis: U_3O_8 at $15/lb, 25% thermal efficiency, credit for unburned U^{235}

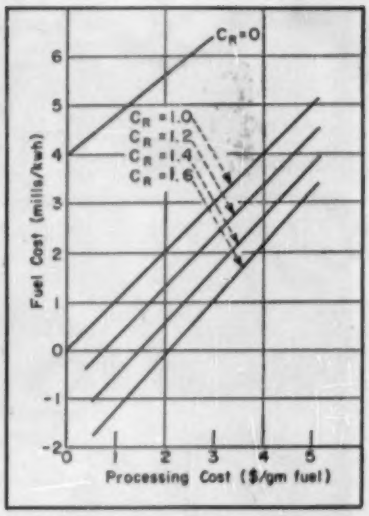

FIG. 7. Fuel costs for highly enriched reactors. Basis: 20% burnup, enriched fuel at $20/gm, process $(4 + C_R)$ gm/gm burned in core

specify the conditions under which nuclear power does become competitive rather than indicating whether or not these conditions actually will be achieved.

In this respect, these studies indicate that the following conditions are necessary for competitive nuclear power. First, one can afford some added expense to insure safety, but probably not more than $10/kw. Second, one cannot afford a large exclusion area. Third, a reasonable price for government-controlled materials is adequate, and in good designs it will not be necessary to have arbitrarily low costs or low rental charges for economic power. Next, a high load factor, preferably about 90%, is important to reduce costs due to the high capital costs. In this regard, capital costs of the nuclear portion of the plant must be brought down to less than $100/kw capacity. A high specific power is an important factor in reducing these costs, but very high temperature operation to achieve high thermal efficiency is not necessary. Finally, fuel element irradiation times up to 10,000 Mwd/ton are required as well as recovery of fissionable material in spent fuel elements. In breeder reactors, processing costs must be kept below $1–2/gm of enriched material handled.

It now appears that most of these specifications will not be too difficult to achieve, say, within the next 10 years with the aid of the present reactor development program. Probably the greatest hurdle to overcome is in reducing capital costs. The successful solution to this depends mainly on the establishment of a competitive nuclear power equipment industry supplementing our present government-sponsored program. When this is accomplished, we will be well on our way toward economic nuclear power.

* * *

The material on which this article is based was presented before the National Industrial Conference Board's third annual meeting on atomic energy in industry, October 13, 1954.

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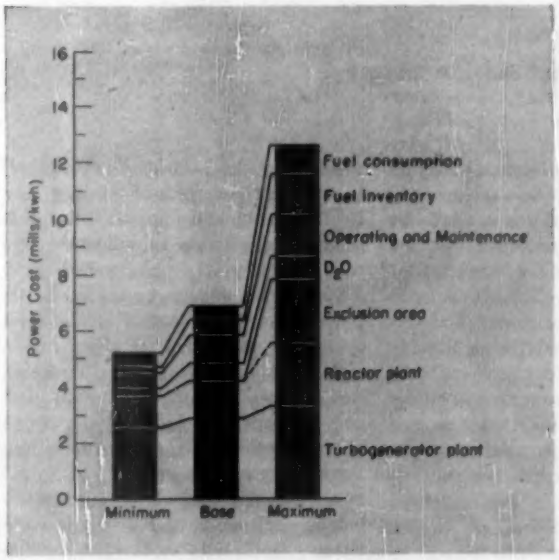

FIG. 8. How nontechnical factors affect estimated nuclear power costs. Variations depend on assumptions chosen

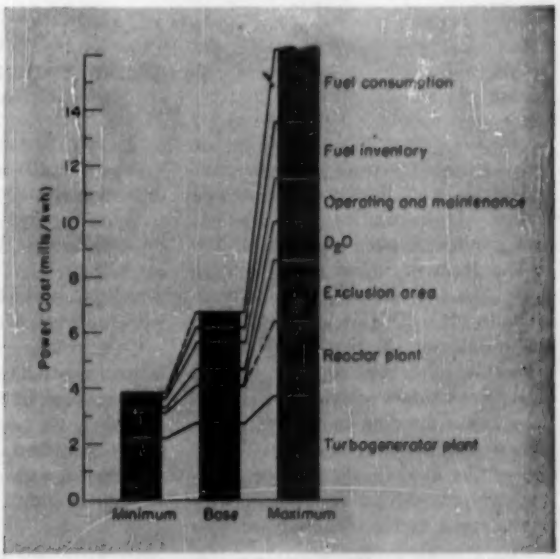

FIG. 9. How technical and nontechnical factors affect estimated nuclear power costs

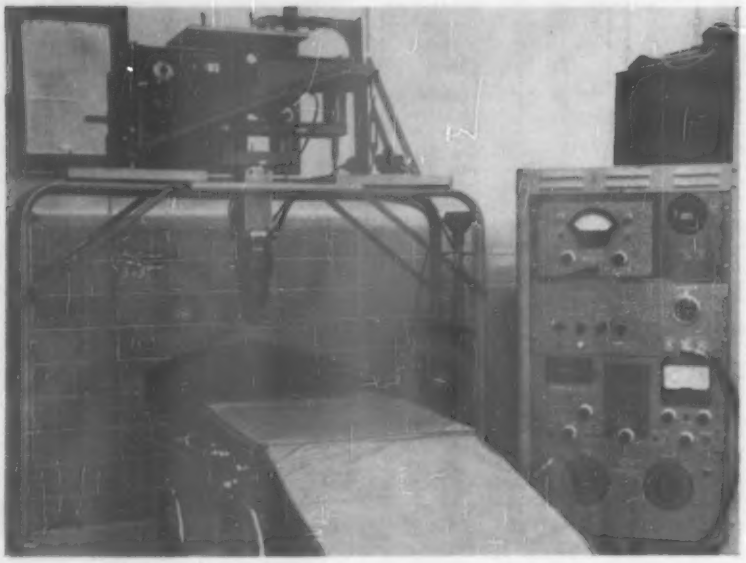

FIG. 1. Complete scanning equipment includes standard commercial power supply, pulse amplifier, single-channel analyzer, scaler, and scanner. Scanning is done in rectangular coordinates, with counter moving along parallel lines. Operator controls separation between lines and scan speed. Stylus-like imprinter makes transverse line each time given number of counts is accumulated. Counting rate is then computed by comparing imprint record with 60 cycle per second test signal. Time for taking gammagram is 30–40 min, including time for positioning patient on adjustable operating table under counter

Simplified Apparatus for

Brain Tumor Surveys

Cutting background by a factor of 10, while sample counting rate is cut only in half is the result of using scintillation detector and pulse-height analyzer to observe only 364-kev gammas from I^{131}. Photons scattered through large angles are not counted

By HERBERT C. ALLEN, Jr.,* and J. R. RISSER†

USE OF RADIOISOTOPES for detection and location of brain tumors is well known. In diagnostic surveys, use has been made of gamma-ray-emitting I^{131} in the form of iodinated fluorescein dyes (*1*) and iodinated human serum albumin (*2*). This article describes a single detector (*3*) that has shown a favorable differential response to relatively weak tumor activity in the presence of surrounding masses of active tissues and blood reservoirs. Principles of the method, detector-head geometry, pulse-height selection, equipment details, and results are presented.

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Success of all tumor-location methods depends primarily on two factors: activity concentration in the tumor; and differential detector response to tumor activity, relative to the larger total activity of the body. This article deals with the second factor alone.

Coincidence methods using annihilation radiation from positron-emitting radioisotopes have been developed by others (*4, 5*). It is felt that a single-detector system, in comparison to a coincidence arrangement, has the advantage of simplicity.

Principles

The γ-ray detector, a NaI crystal mounted on a photomultiplier tube, is recessed in a lead shield so as to be well back from the surface of the head. A hole in the shield defines the solid angle seen by the counter, as well as the volume of the crystal exposed to radiation. The location of the crystal as far as possible from the surface of the head minimizes the effect of the inverse-square law in discriminating against a deep tumor, as compared to a tumor near the surface. Figure 1 shows the complete counting equipment including the scaler and scanner.

A single-channel differential-pulse-height analyzer is used to count only the most intense I^{131} γ, the 364-kev line emitted in 80% of the disintegrations. Selection of a single energy for observa-

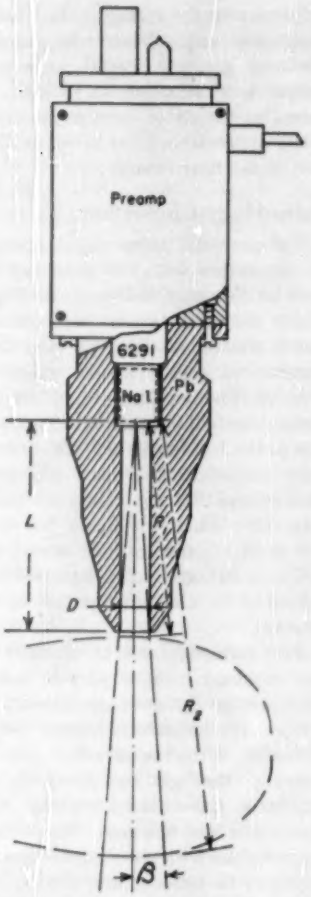

FIG. 2. Geometry of lead shield, NaI detection crystal, and tissue volume under survey. Crystal (1-in. diameter × 1.5-in. high) is commercially sealed in moisture-proof container with MgO reflector. Flat container window is cemented with Dow Corning 200 fluid to flat face of 6291 photomultiplier tube

tion has the effect of lowering background by a much larger factor than it lowers the count from a radioactive tumor in front of the crystal. There are two reasons for this:

First, general laboratory background is fairly well distributed throughout the pulse spectrum. Most of this background is low-energy radiation: for example, X-rays and low-intensity scattered γ-rays from radioisotopes stored in lead shields. High-energy radiation is not, however, negligible. Besides cosmic radiation, it consists of γ-rays from radioisotopes such as Co^{60} that are sometimes unknowingly present during the brain survey. By counting the pulses in a pulse-height interval containing only a small fraction of general background but in which a large fraction of the I^{131} radiation is concentrated, a decrease in background by a factor of 10 can be achieved in our laboratory, while suffering a decrease by about a factor 2 in counting rate from an I^{131} sample.

A second type of background consists of radiation scattered into the counter by the Compton process in the tissue under examination. Since Compton scattering is the principal absorption process in tissue for I^{131} radiation, a considerable portion of radiation emanating from the head has suffered at least one scattering collision. Gamma-rays that suffer a large-angle scattering collision and then enter the counter are not the γ-rays that give information about the presence or absence of a tumor in front of the counter, because they have not originated in the tissue in front of the counter. Since these γ-rays have been reduced in energy by the scattering process, they produce smaller light pulses in the crystal. These scattered photons can be eliminated by this detection equipment if the scattering angle is more than about 60 deg. These scattered photons originate outside the volume under survey by the counter and must be classified as background.

These two types of background are reduced by proper design of the detector-head shield and proper selection of pulse-height interval.

Detector-Head Geometry

Figure 2 is a diagram of the geometrical factors involved in surveying the head. The hole in the lead shield defines a volume of tissue from which γ-rays may be counted. The volume has the shape of a truncated cone with apex in or near the NaI crystal. Photons originating on the axis of the cone have a larger probability of conversion into a pulse in the crystal than those originating off the axis, because of the larger exposed area of the crystal in this direction. For simplicity, however, it is well to define an "equivalent cone," with a sharp boundary, having the property that response to a given source of I^{131} at a given distance will be the same on or off the axis, and that the counting rate when looking into an infinite volume of radioactive tissue will be the same as for the actual case.

Let β denote one-half the apex angle of the equivalent cone, as indicated on the diagram. Then the solid angle Ω in steradians in the equivalent cone is $2\pi(1-\cos\beta)$. In the case where radioactive tissue fills the cone from a distance R_1 cm to a distance R_2 cm from the apex, as shown in Fig. 2, counting rate, r, is given by the expression

$$r = K\frac{C\Omega S}{\mu}[1 - e^{-\mu(R_2-R_1)}] \quad (1)$$

where C is activity per cm^3 of tissue, S is front face area of crystal exposed by the hole in the lead, μ is the linear absorption coefficient in cm^{-1} for γ-rays in tissue, and K is a proportionality constant that depends on units chosen for C and conversion efficiency of the counter. The expression is derived with the simplifying assumption that radioactivity is uniformly distributed and that it is correct to use a single value for absorption coefficient. Use of a single value is equivalent to assuming that the γ-ray spectrum consists of a single line.

While an actual head differs greatly from the simplified model, conclusions can be drawn from the model with regard to factors that determine average counting rate. The product ΩS is determined by the dimensions of the lead-shield hole. The ratio D/L, where D is diameter and L length of hole, determines β and therefore Ω from the approximate relations $\beta \approx \arctan D/2L \approx D/2L$; and $\Omega \approx \pi D^2/4L^2$. Since S is also proportional to D^2, the counting rate is approximately proportional to D^4/L^2. There is thus considerable latitude in the choice of D and L. One can, for example, increase both D and L in such a way as to keep D/L, and consequently Ω, constant while increasing average counting rate by an increase in D^4/L^2. It seems desirable to make D as large as possible up to the limit set by the size of the details under investigation, with Ω as small as consistent with reasonable counting rates. This combination minimizes the variation with depth of the equivalent cone's cross section, making the tissue volume under survey most nearly approach the desired cylindrical form.

The difference $(R_2 - R_1)$ appearing in the exponential term of Eq. 1 represents the only effect of R_1 and R_2 on average counting rate. The distance through the head is $(R_2 - R_1)$. The fact that no factor contains R_1 alone indicates that it is unnecessary to have the lead-shield apex remain in uni-

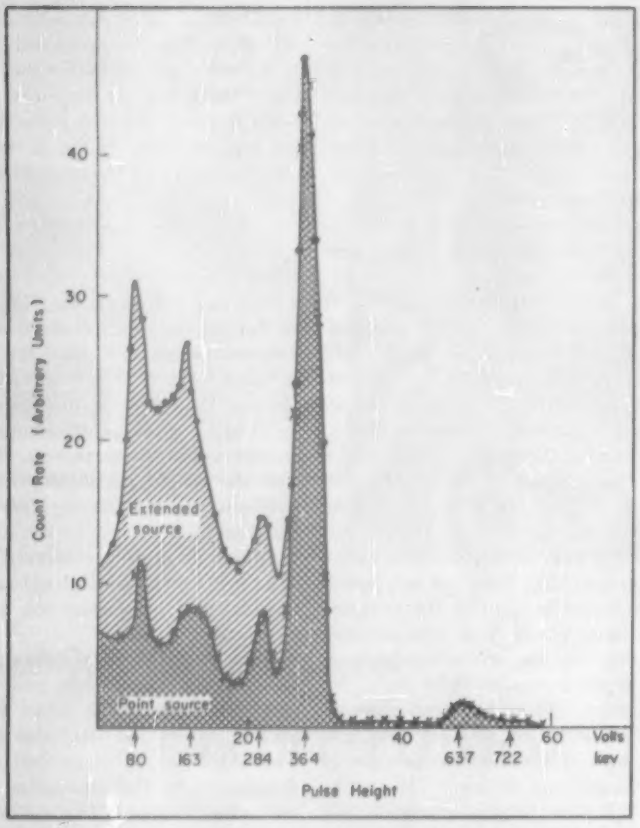

FIG. 3. Pulse spectrum from point and extended sources of I^{131}. Extended source is 3,000-ml spherical bowl of water with uniform I^{131} concentration. Curves are plotted so that peak heights are equal

formly close contact with the head's surface in surveying for tumors. In our laboratory, scanning is done on a plane with patient positioned so the lead shield almost touches his head in the region of maximum interest. From the exponential, it can also be seen that average counting rate is not strongly dependent on $(R_2 - R_1)$, provided $\mu(R_2 - R_1)$ is of the order unity. Because μ in tissue is about 0.1 cm^{-1} for 364-kev γ-rays and the transverse head thickness is 12–15 cm, this condition is satisfied, and average counting rate is nearly independent of distance through the head. Variations of no more than 20–30% are expected, except at the scan's extremes when the counter is moving off the head.

Considerations that apply to average counting rate are not necessarily valid when estimating rate due to a tumor or local activity concentration. Each volume element of the tumor contributes directly as the difference between its activity and the activity of the background tissue it replaces, inversely as the square of the distance to the NaI crystal, and directly as an absorption factor, $e^{-\mu X}$, where X is thickness of overlying tissue between volume element and counter. Because $e^{-\mu X}$ reduces the rate to 30% or less, when X represents total distance through the head, it is clear that an effective survey necessitates scanning opposite sides.

It is therefore pertinent to consider absorption-factor and inverse-square-law effects only over distances halfway in. As an example suppose a small radioactive tumor located 1.5 cm below the surface is compared with an exactly equal one 7 cm down. The inverse-square factor is 1.8 for a 6-in. value of L, with the lead-shield apex in contact with the surface, and the exponential factor is 1.7 for $\mu = 0.1$, both factors being in favor of the tumor near the surface. The product of the factors is 3. This is about as low a factor as can be achieved in favor of detecting a tumor near the surface, rather than a deeper one, unless L can be increased by choosing a larger crystal, or a more penetrating radiation can be used. It seems unreasonable, however, to expect really appreciable gains in either direction in the near future.

Pulse-Height Selection

The case for pulse-height selection in connection with our geometry can best be discussed starting from Fig. 3, which shows the pulse spectrum of a point source of I^{131}. Of the total number of pulses in the spectrum, represented by the area under the curve, one-half lie under the high peak due to the 364-kev γ-ray. In contrast, only about 10% of our laboratory background falls in this pulse-height interval. When surveying for weak I^{131} activity, the ratio of meaningful count to background is improved considerably by observing pulses in this interval.

For example, rates of about 4 cps are obtained from a normal patient 24 hr after intravenous injection of 600 μc of iodinated human serum albumin, with the counter directed laterally through the head in the region of the ventricles about 3 in. above the ear opening. These rates are obtained with the analyzer channel adjusted to include only the 364-kev peak. From the spectrum of Fig. 3 one can infer that a meaningful rate of 8 cps would be obtained without channel discrimination. With source removed, the average laboratory background for this crystal in the lead shield is 4 cps without channel discrimination but above photomultiplier noise, but only about 0.4 cps fall in the channel. Thus, the effect of pulse selection is to reduce laboratory background from a quantity of the same order as the meaningful count to a negligible quantity.

The effect of scattering on the pulse spectrum is also shown in Fig. 3. In the spectrum from an extended source, approximately one-third of the total pulses are under the 364-kev peak, as compared to one-half for a point source. The redistribution is, of course, due to large-angle scattering. No conclusions can be drawn about any γ-rays except the 364-kev one, but simple calculation shows that one-third of the 364-kev photons have suffered enough energy loss through scattering so as no longer to contribute to the peak.

The energy change of a photon

scattered through an angle ϕ can be obtained from the Compton relation

$$E'/E = \frac{1}{1 + \frac{E}{mc^2}(1 - \cos\phi)} \quad (2)$$

where E' and E are respectively the photon energies before and after scattering and mc^2 is the electron rest energy (510 kev). The minimum scattering angle, ϕ, required to reduce the energy of a 364-kev photon so that it cannot contribute to the peak depends on the energy resolution of the crystal-photomultiplier combination. Our resolution gives about 10% full width at half-height for 364-kev gammas and less than 25% full width at the base. Thus a 364-kev photon losing 25% of its energy cannot contribute to the peak. For E'/E equal to 0.75 and E/mc^2 equal to 0.71, a value of 60 deg is obtained for ϕ from Eq. 2. The probability is small that a photon originating in the tissue under survey reaches the crystal, after being scattered 60 deg or more. Except in rare cases, therefore, photons scattered over 60 deg constitute background.

While it is impossible to draw unequivocal conclusions about the much more complicated situation involving the head, it is probable that something like one-third of the I^{131} γ-rays issuing from the head surface have been scattered through angles of 60 deg or more. If so, pulse selection increases the ratio of meaningful count to background by a factor 3/2. This improvement is probably worthwhile. One might speculate that its value would be greatest in surveying near regions of high activity like blood reservoirs, about which one might expect a "halo" of scattered radiation.

Performance

For most of the surveys, the shield hole has been ⅞-in. diameter by 6-in. deep. These dimensions result in a value of about 3.5 deg for β. Experimentally, the counting rate from an I^{131}-point source drops to half-value 3.5 deg off the axis. Good energy resolution contributes to this sensitivity. The crystal-photomultiplier combination is used only if energy resolution is such that full width at half-maximum is no more than 11%, and preferably no more than 10%, when tested with the Cs^{137} 660-kev peak.

As an example of results, the case study on this page is presented. Success has been obtained in a number of cases confirmed by surgery or necropsy. Model studies are in progress to determine the detection threshold for tumors as a function of size, relative activity concentration, and depth.

A Case Study

FIG. 4. Gammagram taken at 4.1 mm/sec. An imprint is made each 4 counts

FIG. 5. Activity map obtained by converting imprint record to counts per second

FIG. 6. Photograph of brain removed at necropsy, showing projections of lesions

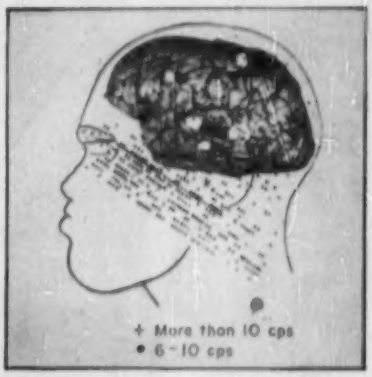

FIG. 7. Combined activity map and picture of brain removed at necropsy

Figure 4 shows a gammagram obtained in a case with necropsy confirmation. Only the left lateral projection is shown. Other projections confirmed the findings. The gammagram was made 60 hr after intravenous injection of 600 μc of iodinated human serum albumin. Careful study reveals areas of increased activity above the left ear. The increased activity noted below a plane through the left ear and eye is due to the radioactive albumin present in the vascular bed of the brain stem and base of the brain. Figure 5 is on activity map of the high counting rate area, labeled according to counting rate. While adjacent inactive areas and the entire corresponding area in the gammagram of the opposite hemisphere showed an activity of about 3 cps, counting rates over the lesions were as high as 10 cps. Figure 6 is a picture of the brain removed at necropsy in which the projection of five metastatic lesions ranging in diameter from 8–18 mm is indicated in white. In the combination photograph and activity map (Fig. 7), the clearest indication is seen just superior to the left ear corresponding to three metastatic lesions.

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Analyzing Beta Absorption Graphically to Identify Emitters

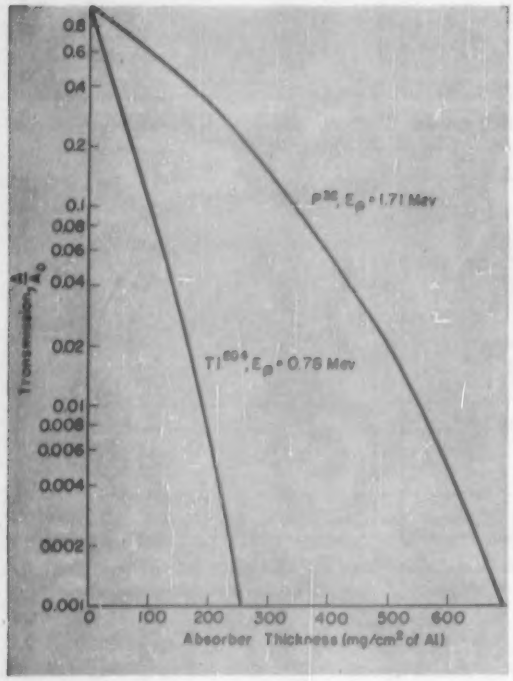

FIG. 1. Typical beta-ray absorption curves

New semiempirical method uses slope of log-log plot of transmissions of beta rays from a standard and an unknown emitter plotted against each other. Isotopic composition and purity can also be determined this way.

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A RAPID METHOD for the graphical determination of beta-ray energy from absorption measurements has been developed. The logarithm of the transmission of the sample and a standard are plotted against each other for each absorber used. The slope of the resulting straight line is characteristic of the maximum beta-ray energy of the sample isotope.

Many simple mixtures can be resolved and percentage composition and component energies approximated. But if the component energies are too close together, the separation cannot be made. Special methods are described that may apply to particular complex mixtures.

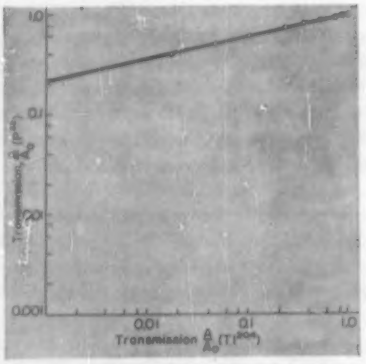

FIG. 2. Comparison of transmission of Tl^{204} betas with those of standard, P^{32}. Transmission of 1 corresponds to no absorber

The procedure is more direct than Feather analysis and can handle any isotope or mixture that the Feather procedure can handle. In addition, it is more readily applied to low-activity samples.

Previous Methods

In the usual beta absorption curve (Fig. 1), the logarithm of the relative activity is plotted against increasing absorber thickness. The plot is not straight, and while the exact shape is very characteristic of a particular isotope, no simple parameter such as the slope can be considered typical. Also, the curve shape is dependent on the physical characteristics of the

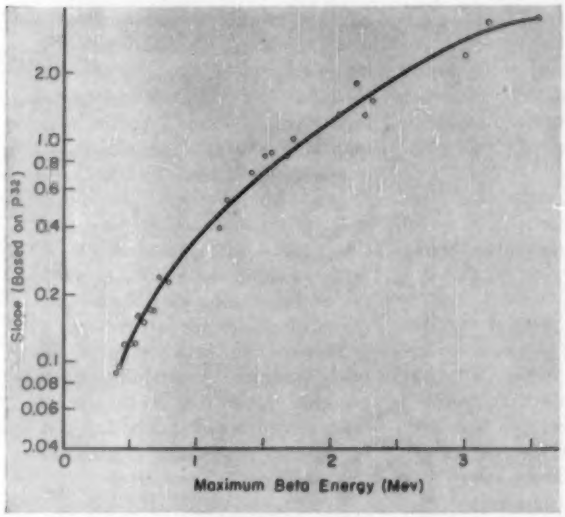

FIG. 3. Slopes of logarithmic curves that used P^{32} as standard are plotted versus maximum beta energy

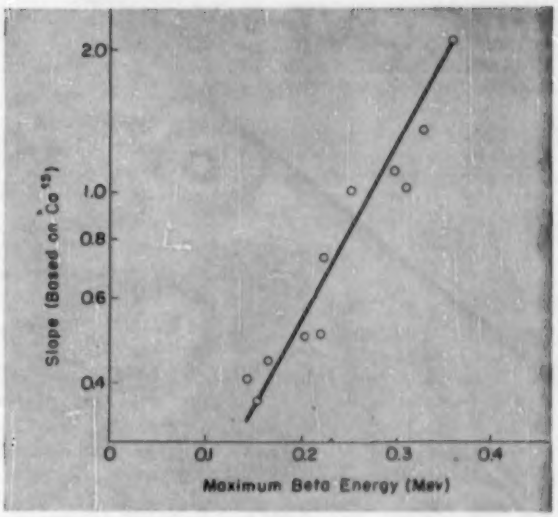

FIG. 4. Slopes of logarithmic curves that used Ca^{45} as standard are plotted versus maximum beta energy

counting equipment, and direct comparisons can only be made under identical counting conditions.

Feather (*1*) and others (*2*) have developed procedures for analysis of beta absorption curves that determine the maximum energy of a beta emitter. These methods depend upon comparison with an isotope of known maximum energy; they yield results in good agreement with spectrometric values.

Briefly, the Feather analysis assumes that the same fractional absorption for each beta emitter corresponds to the same fraction of the total range in the absorbing material. The apparent ranges calculated for several fractional absorptions for the unknown are plotted against the corresponding fraction of total range for the standard isotope. These values are extrapolated to a range fraction of 1.0 to give the range for the unknown. The estimated range can be converted to maximum energy by means of a range-energy chart such as that of Glendenin (*3*).

When two or more components are present, they can be analyzed by breaking down the absorption curve. This process is accurate when removing a gamma component, as gamma absorption is truly exponential. The separation of betas is less accurate, as the individual components are not true exponentials and separation involves linear extrapolation of the stronger component.

The major weakness of Feather analysis and similar systems, however, is their dependence on absorption measurements made near the end of the range. Analytical samples usually are of limited activity; estimating counting rates with heavy absorbers requires impractically long counting periods.

Since the curve shape is very distinctive, the lightly absorbed portions might be taken to characterize an isotope. But nonlinear curves are difficult to match, and multicomponent mixtures cannot be handled this way.

New Method

The new approach is based on comparing the transmissions of an unknown and a standard emitter with the same absorber. Empirically, when the logarithms of the transmissions of the two emitters are plotted against each other for each absorber, a linear relationship is found (Fig. 2). If the normal absorption curve shapes are markedly different for the two isotopes, the logarithmic plot should not be linear, but no marked deviations have been found for over 35 isotopes tested. Phosphorus-32 has been used as the standard emitter, as in Feather analysis, particularly as its single maximum beta energy is intermediate in the range of common isotopes.

The slopes of the logarithmic curves when plotted against maximum beta energy gives a regular curve, Fig. 3, resembling the range-energy curve.* The standard is plotted vertically for convenience in use. The curvature at the low-energy end of Fig. 3 is not disadvantageous, as a slight energy change gives a large change in slope. However, very-low-energy emitters have been characterized by comparison with Ca^{45} (E_{max} = 0.254 Mev) rather than P^{32} (E_{max} = 1.71 Mev). The corresponding curve is shown in Fig. 4.

Actual slopes determined in this laboratory are listed in Table 1. From our experience, these values should be usable for any counting setup that approximates the one described in this article.

Thus four steps are required to determine the maximum energy of a beta emitter:

1. Measure the activity of the sample and of P^{32} with a series of absorbers. (The P^{32} measurement need not be made with every sample

* The slope of a logarithmic curve is $\log (y_2/y_1)/\log (x_2/x_1)$, where (x_1, y_1) and (x_2, y_2) are points on the curve. The process is somewhat simplified if intercepts are used as the two points. For example, in Fig. 2, the intercepts of the Tl^{204} curve are (1.0, 1.0) and (0.001, 0.21). The corresponding slope is, $\log (1.0/0.21)/\log (1.0/0.001) = 0.69/3 = 0.23$. Actually, since similar identical logarithmic scales were used for both axes in these figures, the slope can be obtained directly as the actual slope of the line.

TABLE 1—Standard Slopes

Isotope	E_{max}(4, 5) (Mev)	Slope vs. P^{32}	Slope vs. Ca^{45}
C^{14}	0.155		0.37
P^{32}	1.712	1.0	
S^{35}	0.166		0.44
Cl^{36}	0.713	0.202	
K^{40}	1.40	0.71	
Ca^{45}	0.254	0.038	1.0
Sc^{46}	0.36 (98%)		2.04
Fe^{59}	0.26 (50%)		
	0.46 (50%)	0.12	
Co^{60}	0.31		1.04
Cu^{64}	0.57	0.16	
Sr^{90}	0.537	0.12	
Sr^{89}	1.50	0.85	
Y^{90}	2.18	1.8	
Y^{91}	1.537	0.87	
Zr^{95}	0.4	0.089	
Nb^{95}	0.146		0.41
Mo^{99}	1.22	0.54	
Tc^{99}	0.3		1.2
Ru^{106}	0.222 (90%)		0.50
	0.684 (10%)		
Rh^{106}	3.55 (82%)	3.5	
	2.30 (18%)		
Cd^{115}	1.67	0.84	
In^{114}	2.05 (95%)	1.3	
I^{131}	0.60 (80%)	0.15	
	0.31 (20%)		
Cs^{134}	0.65	0.17	
Cs^{137}	0.51 (95%)	0.12	
	1.2 (5%)		
Ce^{144}	0.30		1.51
	0.17		
Pr^{144}	3.0 (90%)	2.8	
Pm^{147}	0.223		0.73
W^{185}	0.428	0.093	
Os^{191}	0.142		0.15
Ir^{192}	0.67	0.17	
Hg^{203}	0.205		0.50
Tl^{204}	0.783	0.23	
Pb^{212} (ThB)	0.33 (88%)		1.7
	0.57 (12%)		
Bi^{210} (RaE)	1.17	0.4	
Bi^{212} (ThC)	2.25	1.3	
Bi^{214} (RaC)	3.17 (23%)	3.4	
Pa^{234} (UX_2)	2.32 (98%)	1.5	

TABLE 2—Self-Absorption Effects

Isotope	$Ba_3(PO_4)_2$ added (mg)	E_{max} (Mev) Accepted	E_{max} (Mev) Found
P^{32}	0	1.71	1.71
	2.5		1.67
	25		1.64
	250		1.62
Pm^{147}	0	0.22	0.24
	2.5		0.23
	25		0.22
	250		0.20

if the counting setup is maintained constant.)

2. Plot the relative activities of sample against standard for each absorber used on 3-cycle logarithmic paper. The initial activity is that with no added absorber.

3. Determine the slope of the resulting line.

4. Estimate the maximum energy from the slope–energy curve, Fig. 3.

The logarithmic curve can be uniquely determined with a very few absorbers. This is particularly valuable when dealing with low-energy or low-activity samples. In this laboratory, individual isotopes have been identified with only 35 dpm per sample.

Self-absorption affects the slope negligibly. To demonstrate this, samples of P^{32} and Pm^{147} were coprecipitated with varying amounts of $Ba_3(PO_4)_2$ and the energy determined. The results are shown in Table 2.

Mixtures

Even if more than one isotope is present, their beta energies can be determined, provided the energies are appreciably different. Relative amounts can also be fixed. A typical example, the Sr^{90}-Y^{90} equilibrium mixture, is plotted against P^{32} in Fig. 5. The logarithmic curve shows a break. The slope for Y^{90}, the energetic component, is the same as that for Y^{90} separated from its parent. The most energetic component of any mixture thus can be determined directly.

The fraction of the total activity contributed by the energetic component can be found by extrapolating the linear portion. The extrapolated line for the first component terminates at ordinate 0.5, indicating that Y^{90} is 50% of the total activity. (Equilibrium mixtures of Ce^{144}-Pr^{144} and Zr^{95}-Nb^{95} also showed equal fractions, as expected). The residual activity is the contribution of the less energetic component. This difference is replotted against P^{32}, and the resulting line characterizes the second component. This is done in Fig. 5 for Sr^{90}.

The validity of determining composition from the intercept was tested with artificial mixtures of Ce^{144}-Pr^{144} and of Ca^{45} with Y^{91}. The results are shown in Table 3. Continued application of the method in this laboratory has proved its value.

One of the more valuable applications of the method has been analysis of isotope mixtures of the same element. Chemical separations frequently yield samples of two or three isotopes that must be determined separately. While half-life studies may help, energy determinations are more rapid and much simpler.

As might be expected, gamma components show a slope very close to the vertical. No attempt has been made to apply the method to gamma-ray energies using lead absorption, as present methods are satisfactory.

Three or more beta components have been analyzed successfully, but the energies must be well separated. Such mixtures can also be handled by the special procedures given later in this article.

Difficulties

Certain discrepancies have appeared that cannot be satisfactorily explained. Cl^{36} gives an energy of 0.84 Mev by the present method. The accepted value is 0.713 Mev and a Feather analysis shows 0.77 Mev. No reason is known for this variation.

Some isotopes were badly contaminated, but only Os^{191} could not be resolved sufficiently for determining the slope of the logarithmic curve. Ru^{103}-Rh^{103} and Ce^{144}-Pr^{144} equilibrium mixtures contain such large amounts of Ru^{106} and Ce^{141}, respectively, that they cannot be used as equilibrium standards, although the components can be partly resolved.

Certain isotopes emit two or more separate betas. Typical examples are Fe^{59}, Ru^{103} and Ce^{144}. These should show the same break in the logarithmic curve as a mixture of two isotopes but could not be obtained sufficiently free

TABLE 3—Analysis of Mixtures

Mixture	Percent Y^{91} Added	Percent Y^{91} Found	Sample activity (dpm)
Ce^{144}-Pr^{144} and Y^{91}	0	0	15,000
	24	20	2,800
	48	42	4,000
	74	78	6,000
	100	100	23,000
Ca^{45} and Y^{91}	0	0	7,000
	29	28	3,200
	54	40	3,900
	78	75	6,000
	100	100	23,000

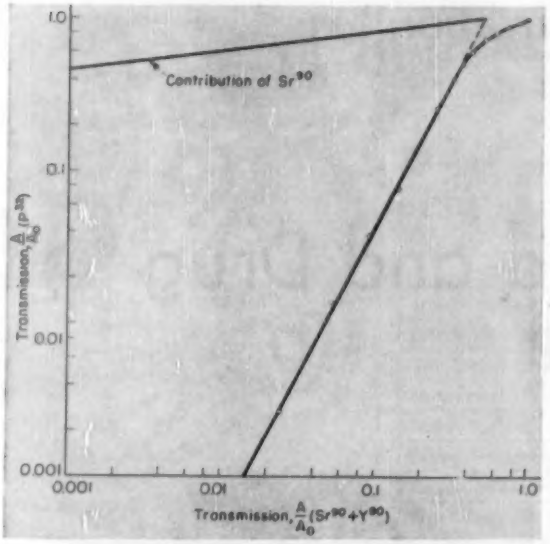

FIG. 5. Mixtures of isotopes can be handled by method illustrated above for Sr^{90}-Y^{90} equilibrium mixture. Beta energies and relative concentrations can be determined

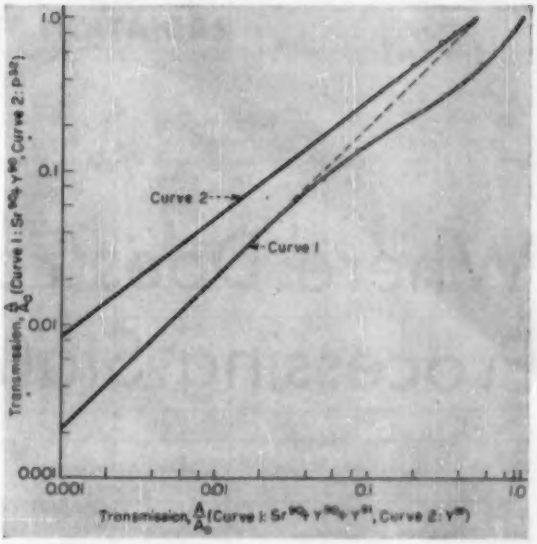

FIG. 6. Plot versus Sr^{90}-Y^{90} standard isolates contribution of Y^{91} mixed with Sr^{90}-Y^{90}. Replotting Y^{91} contribution versus P^{32} standard determines Y^{91} maximum beta energy

of other isotopes to allow resolution of the components.

Special Applications

The logarithmic plot of two samples of the same isotope will show a unit slope. This is also true of any multicomponent systems where the isotopes are present in the same proportion in the two mixtures. For example, two equilibrium mixtures of Sr^{90}-Y^{90} plotted against each other give a logarithmic curve with unit slope. However, an impurity in one would cause a deviation from this line.

This fact can be used to identify the Y^{91} in a three-isotope system containing the Sr^{90}-Y^{90} equilibrium mixture as well. The Y^{91} "impurity" causes a deviation from linearity in a plot of sample against Sr^{90}-Y^{90}. This is shown by curve 1 of Fig. 6.

Curve 1 can be extrapolated with the best line of unit slope to show a fraction of 0.50 for the Sr^{90}-Y^{90}. The combined line of unit slope then represents the Sr^{90}-Y^{90} fraction of the sample. The difference between this line and the experimental curve represents the effect of the Y^{91}. Replotting the difference for each absorber against the P^{32} values for the same absorbers gives curve 2 of Fig. 6. This can be identified as the line for Y^{91}.

This procedure has been extremely valuable for determining impurities in radiochemical precipitates, given an activity of a few thousand dpm. It is only applicable when the energy of the impurity is less than that of the more energetic component of the equilibrium mixture. Fortunately, if the impurity is the most energetic emitter of all, it may be characterized readily by the standard plot against P^{32}.

Another possible application is the study of nonequilibrium conditions in uranium and thorium ores, or in samples representing separated portions of the natural series. For example, the age of a radium preparation could be checked by plotting against a known fresh sample where the Bi^{210} contribution is small.

Changes in highly complex mixtures, such as mixed fission products, are quite apparent. The plot of one mixed sample against another shows marked changes from decay and buildup of different isotopes. Resolution and interpretation of such data would be laborious.

Experimental Equipment

The majority of the isotopes measured were obtained directly from the Isotopes Division of the Atomic Energy Commission at Oak Ridge; Cu^{64} and Fe^{59} were from the Brookhaven reactor.

Most measurements were made with an automatic absorber changer designed and built by the Instruments Branch of the Health and Safety Laboratory. A 24-position absorber wheel and a 6-position sample wheel produce data for six samples without attention. Pulses from a shielded Anton-1007 G-M tube (8.5 mg/cm² window) are fed through a binary scaler or directly into a Streeter-Amet register to record data. Counter background is 6–7 cpm, and geometric efficiency is 17%. Air space, sample to tube window, is 1 cm.

Some measurements were made with the absorber changer operated manually feeding a decade scaler, some with a standard vertical lead castle and decade scaler. In all cases, the same set of Tracerlab aluminum absorbers was used. All instruments gave the same slopes of the log curves.

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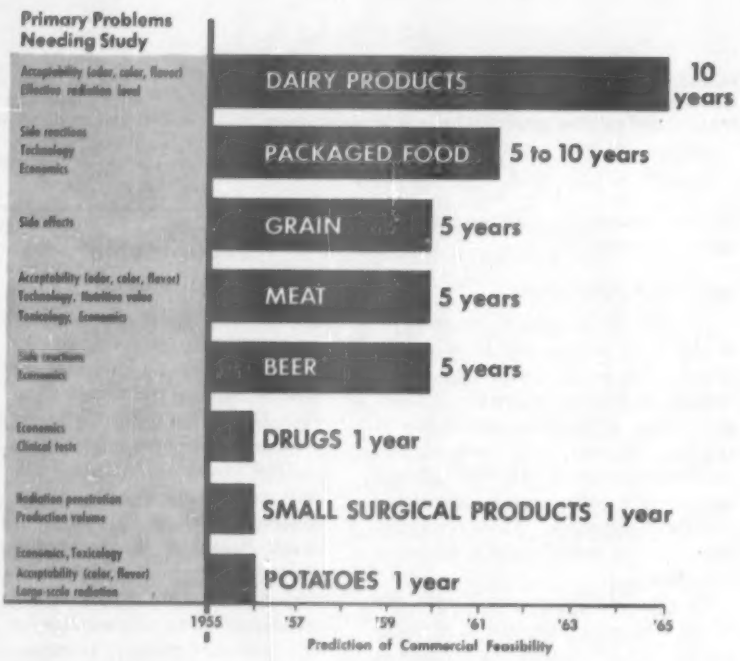
Where Does Food and Drug Processing Stand?*

To evaluate radiation usage, NUCLEONICS surveyed organizations active in the field. Replies indicate this timetable for commercial application . . .



THE NUMBER OF ORGANIZATIONS active in radiation processing research has increased over tenfold from the three laboratories working in 1948. Today over $2-million a year is being spent on research in this field. Why? How?

To provide the answers to these questions, NUCLEONICS has compiled (a) the results of a comprehensive survey; (b) discussion of food and drug industry attitudes; (c) a comparison of usable sources of radiation; (d) a list of current research projects; (e) data that show why the armed forces are spending over $1-million yearly on radiation processing.

To find out the extent of present activity in radiation processing research and the prevailing attitudes towards short- and long-term technical feasibility, 43 questionnaires were sent to government laboratories, educational institutions, and industrial organizations. Of the 37 questionnaires returned, 23 indicated active research programs, 11 indicated no activity, and 3 were returned unanswered. It's significant that one of the three returned without answers is from a drug company known to be a leader in radiation processing research. In fact, returns from the drug industry were much lower than those from the food field. Combining this with the fact that commercial application is expected sooner in the drug field than in food, you logically come to the conclusion that pharmaceutical companies are playing it closer to the chest to preserve commercial advantages in near-future applications. Reinforcing

* This article concludes a special series that started in October, 1953.

this conclusion is the fact that several years ago the drug industry wasn't being nearly so cagey about its radiation work.

But not all drug concerns are active. One company, for example, didn't complete the questionnaire, commenting that it's keeping a watchful eye on the food industry but isn't starting research until radiation sterilization proves economic for its products.

From replies received, we have compiled data showing the number of people working in this field, annual expenditures, and sources of funds.

Staff Size

The 23 organizations replying to the survey employ 196 scientific and technical personnel on radiation-processing research; included are several part-time employees.

In size, three government laboratories lead with an average staff of 38; one group numbers 100. Ten educational institutions employ an average of 5, with the largest a group of 15. Ten industrial research staffs average 3, the largest being 11.

Annual Expenditures

Costs of the 23 research programs are listed in four arbitrary ranges in the illustration on page 38. Only one unit, a government laboratory with contract research at other laboratories included, spends over $100,000 a year. Actually, this one program is in the million-dollar bracket.

Government funds support the majority of government-laboratory and educational-institution programs. However, four of the latter get other support, one being partly self-supported and partly industry-supported, another being entirely self-supported, a third partially self-supported with assistance from both government and industry, and the fourth 50–50 self- and government-supported.

All but one industrial program is self-supported; the only exception gets partial support from government funds. One industrial concern contributes to university research as well as supporting its own program.

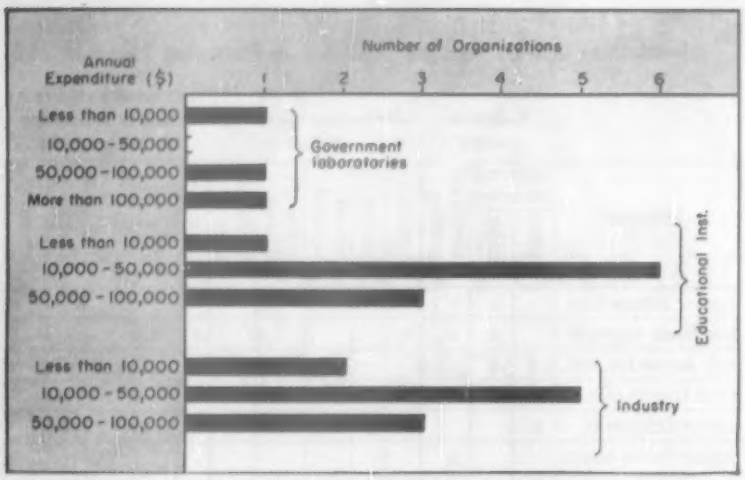
Radiation Sources

Only 10 groups have their own radiation sources; only two industrial groups have radiation sources, and one of these is a rented accelerator. Most industrial groups have access to

Institutions Actively Engaged in Radiation Processing Research

Institution*	Radiation sources: Design and fabrication: Machine	Radiation sources: Design and fabrication: Isotopic	Radiation sources: Dosimetry and monitoring	Technological studies: Processing	Technological studies: Packaging	Technological studies: Drugs and pharmaceut.	Technological studies: Nutrition and toxicology	Technological studies: Microbiology studies	Fundamental studies on nature & prevention of side-reactions: General	Protein	Fat	Vitamins	Carbohydrate
Argonne National Labs.		x											
Brookhaven Natl. Labs.		x	x	x					x				
Natl. Reactor Test. Stat.		x											
Naval Research Labs.			x										
Applied Radiation Co.	x												
Dugway Proving Grounds			x										
Electronized Chem. Corp.	x												
High Voltage Eng. Corp.	x												
Vitro Corp. of Amer.		x											
Alabama Polytechnic							x						
Amer. Meat Inst. Found.				x					x	x	x		
Battelle Memorial	x			x	x	x	x	x	x	x	x		
Columbia University			x	x		x		x					
Food Research Inst.								x					
G.E. Res. Labs. (Knolls)								x	x	x			
Hormel Inst.											x		
U. of Illinois							x				x		x
Iowa State College										x			
Mass. Inst. of Tech.			x	x	x	x	x	x	x	x	x	x	x
Med. Nutr. Lab. (Army)							x			x	x		
Univ. of Michigan		x	x	x	x	x	x	x	x				
Michigan State College								x					
Natl. Canners Assoc.				x				x					
Ohio State Univ.										x			x
Oregon State College				x			x	x	x	x	x		x
Pioneering Res. Lab. (QM)			x						x				
Food & Cont'r. Inst. (QM)			x	x	x		x	x	x	x	x	x	x
Swift & Co.				x	x		x	x	x				
American Can Co.				x	x		x	x					
Ethicon Suture Labs.								x	x				
The Upjohn Co.						x		x	x				
Schering Corp.						x		x					
Canada Packers Ltd.													
General Foods Corp.				x			x	x	x	x	x	x	x
Continental Can Co.				x	x								
Gerber Foods, Inc.				x	x						x		
Oscar Mayer Co.				x	x			x					
Parke, Davis & Co.						x							
Reynolds Metal Co.					x				x				
Cornell University				x						x		x	x
40				16	10	7	11	17	14	11	10	4	7

*Information on several of these institutions, not applied in the survey, was obtained from other sources.



COMPARISON of annual expenditures for radiation processing research

Sources of Radiation:

Accelerators		Isotopes*	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Available in outputs required for processing	Reliability of accelerators for food and drug plants not yet established	Constant emission at known decay rates and energies	Not yet available in required quantities
Can be stopped or started at will	Penetration of conventional containers not yet possible; may be achieved at later date	Penetrate conventional containers	Periodic replenishment required dependent on half-lives
Very mobile		Mobile, if sources are concentrated packaged fission products or separated isotopes	Energy always being emitted; remote control requirement greater
			Nonmobile, if sources are reactors or reactor fuel streams

*Although costs of presently available processed isotopes that produce radiation quantities comparable to those from accelerators would be in the multimillion-dollar range, processing plants now under construction are expected to reduce costs considerably.

These Accelerators Are Available

Name	Manufacturer	Voltage (Mev)	Average beam current (ma)	Power output (watts)	Cost ($)
Resonant transformer	General Electric	1	0.50	500	Lease basis
Resonant transformer	General Electric	1-3.5	5-8	?	?
Van de Graaff	High Voltage	1	0.025	25	18,400
Van de Graaff	High Voltage	2	0.250	500	56,200
Van de Graaff	High Voltage	3	4.0	12,000	400,000
Capacitron	Electronized Chem.	2.5	?	1,000(?)	?
Linear electron	Metropolitan Vickers	4	0.125	500	?
Linear electron	Metropolitan Vickers	8	0.031	250	?
Linear electron	N. A. Philips	15	0.025(?)	375(?)	175,000
Linear electron	Applied Radiation	4-8	?	?	?
Linear electron	High Voltage	4-6	0.375-0.250	1,500	?
Linear electron	High Voltage	10-50	0.0002	2-10	250,000

irradiation facilities in university or government laboratories and thus are not using their own facilities to carry out research programs.

Included in the 21 radiation sources in use are 12 isotopic and fission-product sources, 4 accelerators, 4 X-ray machines, and 1 reactor.

Feasibility

One section of the questionnaire asked what products could in the future be radiation processed, when the technology would allow commercial use, and what problems still had to be solved before such use would be possible. The illustration on page 36 summarizes the results. The most frequently mentioned product was meat; one company estimates that annual dollar volume of meat to which radiation processing could be applied is $2-billion.

If you analyze the problems listed, it's easy to see why certain applications will come along faster than others. L. E. Clifcorn has enumerated the problems and their extent in appraising the food-industry attitude (p. 39). In the drug industry, fewer problems are evident. First of all, side effects are not as important—the amount of medicinals used by humans is insignificant compared to the food they eat. This also lessens the toxicological problem, although Food and Drug Administration requirements must still be met. But some drug companies have accumulated results from chemical, biological and clinical testing for several years, and FDA approval seems imminent. Rumor has it that preliminary FDA approval has been obtained by two or more companies.

Unfortunately, the food field doesn't have such a backlog of data. It's significant, however, that Army's Quartermaster Corps and Surgeon General are starting human feeding studies this month.

Adequate radiation sources for production-line processing are cited as a primary need by one drug-industry company. Limited penetration of accelerator-produced radiation limits the number of products it could process now, and isotopic sources with large enough power outputs are not available.

In the drug field, economics is cited as a problem, but it is alleviated by the fact that radiation processing can provide "guaranteed" sterilization—which most processes, such as aseptic han-

dling, that are used with heat-sensitive pharmaceuticals cannot do.

Public Discussion

No objections were raised to public discussion of radiation processing by those replying to the survey—*if the information was presented properly.* The primary objection was that over-optimistic announcements and predictions—"unbalanced discussion" and "implications that problems are minor"—have misled the public and perhaps made the future job of selling radiation processing to the consumer more difficult. A minority felt that public enlightenment would be propitious at this time, however.

But technical publication of results was endorsed heartily as a means of furthering progress. The objection, twice mentioned, was that competition would be aided and commercial advantage lost.

Numerically, 13 organizations have published results in technical journals; 19 plan to. Two industrial concerns have used radiation processing as the basis for advertisements; five have also used it for promotional material, as have one educational institution and one government laboratory.

The Food Industry's Attitude Toward Radiation Sterilization

Here's a down-to-earth appraisal of radiation processing from the viewpoint of a food-industry executive. It shows how close radiation processing comes to meeting the industry's criteria for a new process and its products

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BEFORE DISCUSSING the food industry's attitude toward radiation sterilization, it is vitally important to look at the factors influencing opinions on this subject. The attitude of an industry is the collective average opinion of all of its executives. Food industry executives are usually not scientifically trained and, with all due credit to their ability and good judgment, on a subject as complex as this, it is often difficult for them to differentiate between facts and opinions.

Scientists working on radiation sterilization of foods have expressed widely varying degrees of optimism on the feasibility of commercial application of this principle, making it readily understandable why food industry executives are justifiably confused about this subject.

The purpose of this article is to relate the present status of radiation sterilization to the criteria food-industry executives use to judge new processes. An appraisal of the specific factors involved should give a good picture of what the industry's attitude should be on this subject.

In the food industry, the success of a new process is determined by analyses of the products produced by it. If the new process enables the uniform production of new or improved food products that meet a consumer need or desire at a reasonable cost, the process will most likely be successful. Commercial possibilities of radiation sterilization must be evaluated by these same criteria.

Technical Feasibility

Radiation sterilization offers the first promising new principle of food sterilization since Nicholas Appert discovered the art of canning in 1809. On an experimental basis, radiation sterilization of foods has been accomplished using cathode or beta rays, gamma rays, and X-rays. All three types of radiation destroy bacteria at about the same dosage level—usually 1,500,000 to 3,000,000 rep is sufficient. By comparison, the estimated lethal dose for man is 800 rep and for insects about 25,000 (*1*).

With accelerator-produced cathode rays, sterilization dosages are achieved in a matter of seconds. However, the effective depth of penetration into a moist food is about 0.5 cm for each Mev of particle energy, limiting the food thickness. Simultaneous irradiation from the top and bottom would enable doubling the thickness. It is apparent that if cathode rays are used for sterilization of foods, thin layers of food must be treated followed by aseptic packaging, or sufficiently thin packages of food must be prepared to permit in-package sterilization.

Gamma rays emitted from gross fission products will penetrate 6 to 9 in. of water before losing half their energy. Using proper radiation geometries, gamma rays could be used to sterilize No. 10 cans of food.

Today, the efforts of the food industry, universities, research institutions, the government, and the military are being capably coordinated in the Quartermaster Food and Container Institute radiation sterilization program. The food industry regards such research as having the possibility of eventually changing containers, preparation and processing methods, and distribution and marketing practices of food products.

Economics

With regard to cost and production rates, cathode-ray accelerators can be obtained from the 1-Mev 25-watt size costing $20,000 up to the 3- to 5-Mev 12-kw ones costing $500,000. The larger units, utilized at full beam capacity, are capable of sterilizing food at approximately 5,000 lb/hr. Estimates based on 5-year amortization of equipment, plus operating costs indicate that radiation sterilization would cost 2 to 8 cents/lb. For comparison, a single-line pea cannery capable of canning 12,000–15,000 lb/hr uses steam at 0.002 cents/lb for sterilization. Canned ham, produced at 10,000 lb/day, requires about 0.1 cent/lb for steam.

Estimates on using gamma radiations from gross fission products cannot be made until further information on supply and costs are available from the Atomic Energy Commission. Since soft X-rays are produced mechanically

with a loss of about 95% of the original electrical energy, their cost of production seems to be excessive.

Taste and Uniformity

The food industry has built its reputation and success on the principle that foods must look and taste good and that uniform product quality must be maintained. Unfortunately, in radiation sterilization of foods, some undesirable chemical and physical changes take place. These changes are in direct proportion to the radiation dosage applied and vary in degree from product to product. For example, bread, liver, and green beans have not been observed by most investigators to develop significant off-flavors and off-odors. However, detectable off-flavors and odors are produced in milk with radiation levels of about 5 to 10% of those necessary for sterilization, while ten times these dosages produce no off-flavor in apple juice (*1, 2*). For meat surface pasteurization, treatments up to 60,000 rep have produced insignificant off-flavors, while at sterilizing dosages of 2-million rep, off-flavors are generally produced.

The off-flavor–off-odor problem in irradiated foods is the number one problem that must be overcome before the food industry can make wide application of this process. Research workers express confidence that by the proper selection and/or combination of various techniques foods can usually be protected against radiation-caused flavor changes. This problem is being pursued diligently in various laboratories using both the technical and fundamental methods of approach.

Huber, Brasch and Waly (*3*) describe a number of protective methods to control quality characteristics of foods being irradiated such as irradiation in the frozen state, in vacuum, under inert gas, in the presence of various chemicals, with the elimination of oxygen dissolved in the foodstuff prior to irradiation, and combinations of these treatments. Proctor and Goldblith (*4*) were successful in eliminating off-flavors in several foods by adding free-radical acceptors to the product prior to irradiation. The chances of overcoming this problem are further encouraged by the fact that some foods are not significantly affected by levels of radiation necessary for sterilization. Also, the same degree of off-flavor is not consistently produced in the same foods, i.e., meat a typical example.

Wholesomeness

Negative results obtained with irradiated samples of 24 elements occurring in food indicate that induced radioactivity is no problem in radiation sterilization of foods (*5*). However, before radiation-processed foods can be recommended for large-scale consumption by humans, conclusive evidence of the absence of acute or chronic toxicity must be established. Feeding tests with rats and other animals have shown no indication of any toxic effects.

Wholesomeness studies will have to be extensive and sufficiently comprehensive to satisfy Food and Drug Administration requirements (*6*). Researchers feel that enough work should be done now on the food products where radiation sterilization shows promise to establish the general physiological characteristics of such foods—with full knowledge that complete toxicological appraisals must be obtained after food preparation and irradiation techniques are modified to give products with favorable quality characteristics.

Nutrition

Another important factor in evaluating radiation sterilization of foods is its effects on food nutrients. Some sacrifices in nutrients are made in all types of food preparation, processing, and preservation. The same must be true for radiation sterilization. In early investigations, Proctor and Goldblith (*7*) found that more niacin was destroyed in dilute than in concentrated solutions. O'Meara (*8*) and Proctor and O'Meara (*9*) concluded that irradiation by high-voltage cathode rays caused a considerable loss in the reduced form of vitamin C, but that this loss was negligible when the medium was irradiated in the frozen state. In work on irradiated milk, Gaden (*10*) reported that at radiation dosages approaching that required for sterilization, 47% of the riboflavin, 100% of the ascorbic acid, and 85% of vitamin A contents were destroyed. Proctor and Bhatia (*11, 12*) also found that amino acids in dilute solutions were easily destroyed by ionizing radiations but that they were practically unaffected in whole protein as it exists in its natural environment.

It is generally believed that when

Why the Armed Forces Are Studying Radiation Processing

Colonel W. D. Jackson, chief of the research and development division of the U. S. Army's Office of the Quartermaster General, cites three vital areas that will benefit if radiation processing proves practical:

1. *The U. S. armed forces are the world's largest buyers of subsistence items. Total Department of Defense subsistence procurement (excluding local Navy purchases) were over $4-billion ($1¾-billion in perishables) in 1945 and hit a peacetime low of $1½-billion (over $1¼-billion in perishables) in 1950. Army procurement of meats in wartime reached about 2¾-billion pounds of fresh meat and ¾-billion pounds of canned meat in 1944; in peacetime (1949), fresh-meat procurement sank to a minimum of 180-million pounds, and canned to a comparatively negligible amount.*

The shipping cost from Chicago to Tokyo is 8.7 cents/lb for frozen meat and 3 cents for nonperishables. When possible, each man receives 6.0 lb of food per day, 2.9 lb of which are perishables (roughly 2.3 lb of the latter shipped from the U. S.). Thus, perishables impose an additional shipping cost of 11 cents per man per day.

2. *The supply system for the armed forces is geographically extensive. Supplying perishables to overseas areas involves warehouses, railroad reefer cars, refrigerator ships, trucks, and trailers. Radiation processing could relieve the congestion of machinery-laden naval vessels and ameliorate the expense of static refrigerated facilities.*

3. *Food quality or quantity is a controlling factor in the success of many tactical operations. Reduction in the frequency of resupplying warships with perishables would increase their cruising range—particularly in the case of nuclear-powered vessels.*

know-how is developed to inhibit deleterious chemical reactions taking place during irradiation to overcome the off-flavor–off-odor problem, by the same common denominator the toxicity and nutrient retention problems will also be alleviated.

Shelf Life

Many reports on irradiated foods have not given proper consideration to this factor. High quality immediately after sterilization means little unless it can be maintained for sufficient time to allow the food to be handled through various distribution channels. Food commodities treated by various preparatory and irradiation techniques must be quality tested and accurately evaluated after storage for various lengths of time and under various temperature conditions. The main reason this has not been done is that satisfactory initial quality has not been obtained thus far to justify comprehensive storage tests.

Increasing the shelf life of food products offers the most promising introductory application of ionizing radiations in the food industry. Precut, prepackaged raw meats have shown 5–20 times extended refrigerator storage life when given surface pasteurization treatments at low dosage levels (20,000 rep). Similarly, fruits have shown extended life by flexible packaging and surface treatment. The fact that rather low levels of radiation have been found to inhibit sprouting of potatoes is encouraging. After 18 months storage, potatoes irradiated with 20,000 rep had excellent appearance and taste; weight loss during storage was greatly reduced and sprouting completely inhibited (*13*). Prevention of insect reproduction and consequent infestation of grain or other dry foods can be attained with low radiation doses compared to those needed for sterilization (*14*). In addition, a moderate investment in radiation equipment should be sufficient to cover a rather large production capacity. One of these may be the first application of ionizing radiation in the food industry.

Packaging Requirements

If radiation sterilization of foods becomes a reality, container requirements may be changed considerably. In comparison with thermal processing, containers will no longer have to withstand internal pressure; this would change the packaging specifications of many products from that of rigid to nonrigid containers. If thin layers of foods are sterilized by cathode rays followed by aseptic canning, a wide variety of containers may be used provided they can be previously sterilized and lend themselves conveniently to aseptic filling with presterilized food and subsequent sealing.

Regarding packaging materials, information currently available indicates that radiation dosages, at levels required for sterilization, have no deleterious effects with the exception that glass is darkened to some degree.

Consumer Acceptance

Whether the consumer prefers raw or partially cooked products in preference to those requiring little or no preparation before serving must be taken into consideration and particularly emphasizes the fact that consumer reaction to new products and consumer education are most important factors and difficult areas in which to predict results.

If the process is successful, the matter of the degree of cooking required by the consumer is one that must be determined by the food processor. It may be desirable to cook some foods partially or completely prior to irradiation for best table acceptance. Specific to this process is the opportunity for a wide range of precooking of preserved foods.

The heat treatment for precooking some foods prior to irradiation may or may not be coincident with the amount of heat required for enzyme destruction. Foods spoil most frequently because of bacteriological and/or enzymatic action. Although ionizing radiations are effective in destroying bacteria, about 5 to 30 times the dosage is required to destroy enzymes. Such radiation dosages denaturize foods and render them inedible. Therefore, a mild heat treatment to destroy enzymes, followed by irradiation, seems to be a logical possible treatment for investigation for some foods.

Conclusions

All of the factors previously discussed are important in developing perspective toward the commercial possibilities of radiation sterilization. However, it is now important to take the position of an executive in the food industry. Besides rendering a service to our consuming public, our respective companies must make a profit. Therefore, a thorough evaluation must be made of what foods may be benefited by this new process of cold sterilization and whether these benefits are sufficient to carry—at least in the early stages—(a) the higher capital costs for equipment, (b) the higher operating costs, and (c) costs for consumer education to foods having new sensory characteristics and new cooking requirements. It is fully recognized that these evaluations must follow the outcome of investigations at the fundamental research level to determine whether the objectives of the food industry can first be achieved by any means at any cost through radiation sterilization.

The food industry has long been recognized as a pioneering and progressive group, constantly looking for new products, new processes, and changes that will have significant effects in the American competitive system. The support of food research and technology has resulted in significant contributions, which could only have been made possible by large-scale effort and the appreciation and support of the scientific method of approach. Patience and confidence in research to show the possibilities of this new and interesting process must prevail, as well as a confidence in our ability to provide radiation energy in the future at a lower and more economical cost. The attitude of the food industry is believed to be consistent with the foregoing conclusions, with a general belief that there will be some application of ionizing radiations in the food industry within the next ten years.

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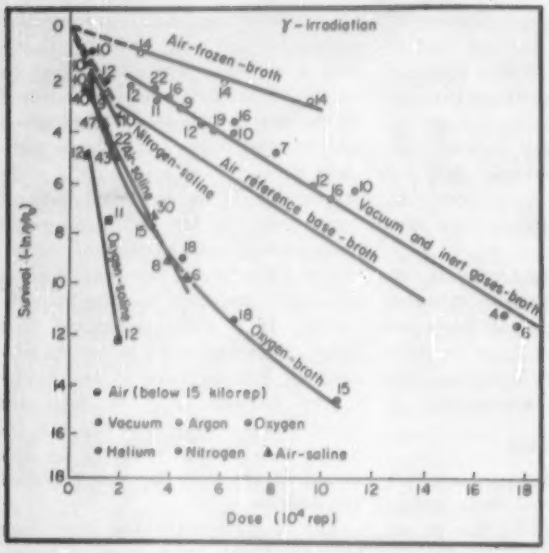

FIG. 1. Radioresistance of *E. Coli* for different environments. Numbers of samples irradiated is shown at each point

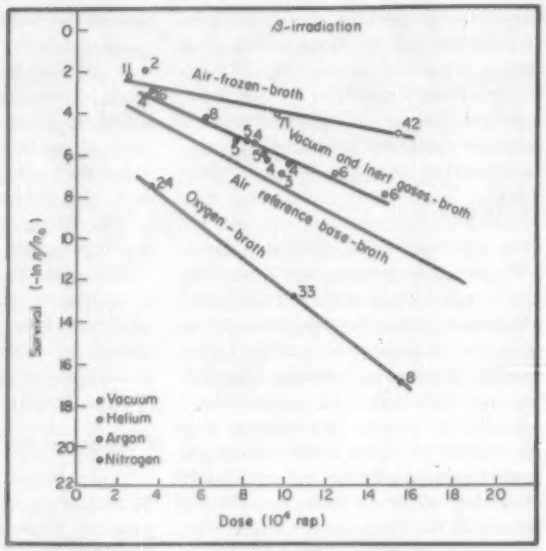

FIG. 2. Environmental effects on survival of *E. Coli* when irradiated with 3-Mev beta rays from a Van de Graaff

How Processing Conditions Affect

An inert or vacuum atmosphere, frozen suspension medium, or more complex organic medium decrease radiosensitivity of E. Coli when exposed to irradiation. These experiments are directly applicable to possible food processing methods

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IN STERILIZING FOODS with ionizing radiation, the dose required for bacterial destruction may be governed by a number of factors, including:

1. Type of radiation employed.
2. Different gases in food container.
3. Temperature of irradiation.
4. Composition of food material.

The role played by the type of radiation employed has been adequately considered in comparative studies of the bactericidal efficiencies of cathode rays, X-rays, and gamma rays (*1*). This article presents the results of studies relating to the other three factors. Excellent researches dealing with some of the experimental and theoretical aspects of these factors have already been reported by many other investigators. Investigations up to 1952 have been summarized (*2*).*

Effect of Atmosphere

It is well-known that oxygen can influence the effect of ionizing radiation upon matter in which water is present. Although details of the radiation chemistry of water in the presence of oxygen are still somewhat speculative, it is thought that the bulk of reactions due to the presence of oxygen originate from the hydroperoxyl free radical (HO_2)—a powerful reducing agent—formed from hydrogen atoms arising in water decomposition

$$H + O_2 \rightarrow HO_2 \qquad (1)$$

The HO_2 radical may initiate additional mechanisms for the decomposition of water

$$2H_2O + HO_2 \rightarrow 2H_2O_2 + H \qquad (2)$$

* A review of similar literature from 1952 to date is at present being prepared in the Department of Food Technology at MIT.

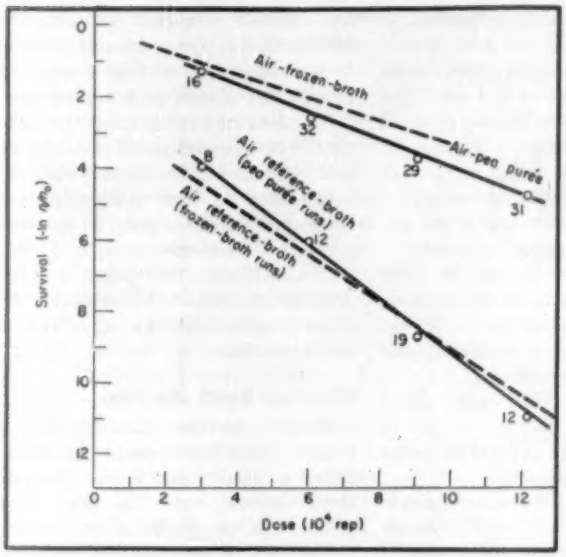

FIG. 3. Pea purée suspension protects *E. Coli* when irradiated with gamma rays

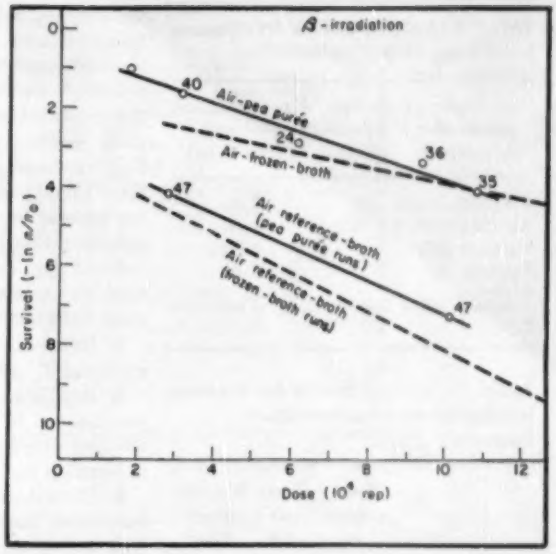

FIG. 4. In beta-ray irradiation, pea purée suspension medium still protects *E. Coli*

Microorganism Radioresistance

The HO_2 radical may also readily oxidize inorganic or organic matter dissolved in the water.

In addition more hydroxyl radicals (also powerful oxidizing agents) may be produced in reactions such as

$$H + H_2O_2 \rightarrow H_2O + OH \quad (3)$$

Thus, the presence of oxygen might produce greater concentrations of radicals that are powerful oxidizing agents, that would affect bacteria by being formed within them or by entering after diffusion from the medium.

The effect of the presence of oxygen during irradiation of an organism can be ascertained by comparing results obtained when the organism is irradiated in the presence of air and in the absence of air (in vacuum). This comparison has been made for nutrient-broth suspensions of the nonsporulating bacteria *E. coli* irradiated with gamma rays from Co^{60}. The section, "Methods and Equipment," on page 45 gives the experimental techniques used. The data obtained are presented in Table 1. These data also illustrate the variation in mean lethal dose (D_0) for 3-ml and 5-ml *E. coli* suspensions.

The mean D_0 value for 5-ml samples irradiated in air is greater than that for 3-ml samples. This difference is ascribable to the difference in air spaces in the identical ampoules that contained all samples. A greater amount of oxygen was available to the 3-ml samples than to the 5-ml samples. Also, smaller-volume samples must have consumed smaller amounts of oxygen, and the net effect was that, for a given dose rate, the 5-ml suspensions used up the available oxygen before the 3-ml suspensions did.

This explanation is substantiated by the fact that the D_0 values for the 3-ml and 5-ml volumes of *E. coli* irradiated in vacuum are identical and higher than those for air-irradiated samples.

Effect of oxygen. To ascertain whether other species of microorganisms show the peculiar volume effect alluded to previously, seven other nonsporulating species of bacteria were exposed to gamma radiation from the same source. About half the samples were 3 ml and half 5 ml in volume. Although the number of irradiated samples of each of these species was not as large as the number in the case of *E. coli*, the results (Table 2) do indicate definite trends of oxygen susceptibility in five of the seven species studied. Two species, *Ps. fluorescens* and *Ps. aeruginosa*, did not indicate this susceptibility. However, the absence of volume effects in these particular instances is believed to be explained by the low D_0 values for these organisms rather than by any nonsusceptibility to oxygen. The D_0 values for these two organisms are considerably lower than those for the other organisms cited in Table 2, which indicates that the dose would have destroyed a considerably larger proportion of the organisms before the oxygen in the ampoules was exhausted. Under these conditions, any oxygen effect ascribable to difference in volumes of suspension would be obscured.

Effects of different atmospheres. To investigate further the atmosphere effect on bacterial radiation sensitivity, suspensions of *E. coli* in nutrient broth were exposed to Co^{60} gamma rays under different gaseous atmospheres. Three-ml aliquots of *E. coli* suspensions were irradiated after being sealed under vacuum or in air, helium, argon,

TABLE 1—Volume Effects for Gamma Irradiation of *E. Coli

Atmosphere and number of samples	*Sample volume (ml)*	*Mean lethal dose (10^4 rep) (mean value)*
Air (53)	3	0.64
Air (66)	5	1.01
Vacuum (67)	3	1.64
Vacuum (67)	5	1.63

* Data taken from Table 1 of reference 7.

TABLE 2—Volume Effects for Gamma Irradiation of Air-Atmosphere Bacteria*

Organism	*Number of samples*	*Sample volume (ml)*	*Weighted mean lethal dose (10^4 rep)*
A. aerogenes	16	3	0.92
	16	5	1.14
S. aureus	16	3	1.27
	12	5	2.20
S. albus	16	3	0.84
	16	5	1.02
S. faecalis	16	3	2.63
	11	5	3.77
C. zerose	12	3	0.79
	16	5	1.53
Ps. fluorescens	14	3	0.20
	12	5	0.24
Ps. aeruginosa	5	3	0.32
	7	5	0.34

* Data taken from Tables 2 and 3 of reference 7.

nitrogen, or oxygen (Fig. 1). Similar experiments were conducted in which the type of radiation employed was 3-Mev cathode rays from a Van de Graaff accelerator (Fig. 2). In still other experiments, *E. coli* was suspended in saline solutions (3 ml) and exposed to gamma rays (Fig. 1).

The air reference base-broth survival curves in Figs. 1 and 2 were calculated from the experimental points of all air-reference survival curves obtained for the different conditions in the respective figures. Experimental points for the inert gas and vacuum curves in Figs. 1 and 2 were corrected for slight differences in their corresponding air-reference curves by giving them vertical displacements from the air reference base-broth curve equal to the vertical displacements from their own air-reference curves. Because there seems to be no consistent difference in radioresistance of *E. coli* with any of the inert gases or vacuum atmospheres, the single curves shown in Figs. 1 and 2 were statistically calculated from all these points. Individual curves for the frozen-air and oxygen runs in Figs. 1 and 2 were different enough for comparison so no correction for air-reference differences was required.

From the data obtained in these experiments with gamma and cathode rays, these conclusions can be drawn:

1. Increased oxygen tension causes increased *E. coli* radiosensitivity.

2. Irradiation of *E. coli* under vacuum or in a helium, argon, or nitrogen atmosphere appears to result in identical survival curves.

3. There is a break in the air reference base-broth curve for *E. coli* at about 15,000 rep. At doses above 15,000 rep, the slope of the air reference base-broth curve is virtually equal to that of the vacuum-inert-gas curve. At doses below 15,000 rep, the slope appears to be a function of oxygen content of the ampoule in which the sample is sealed. It is not known for certain whether this dose level represents the point of oxygen depletion for the particular ampoules and volumes used. Direct oxygen-content measurements of irradiated ampoules are now underway. The survival curve for samples with pure oxygen atmosphere irradiated by gamma rays tends to curve convex downward, and the slope appears to approach that of the vacuum-inert-gas curve. This result supports further the explanation of oxygen exhaustion.

4. The air-saline curve does not exhibit an appreciable break at low doses. This may be because oxygen was not exhausted as quickly in the air-saline suspensions as in the broth suspensions, and the implication is that the broth itself is responsible for the more rapid oxygen consumption.

Effect of Frozen Medium

Suspensions of *E. coli* in the frozen state were irradiated both by gamma rays and cathode rays. The results (Figs. 1 and 2) indicate that freezing caused a great increase in radioresistance, the slopes of the frozen-broth survival curves being less steep than those of the vacuum-inert-gases-broth curves. This increase in *E. coli* radioresistance may be due to the decreased diffusion in frozen suspensions of the free radicals produced by radiation. Moreover, the oxygen-exhaustion effect is not apparent in this case, even though frozen samples contained air.

The data on freezing effect are based on 356 samples irradiated in nonfrozen and frozen states (both with air atmospheres). The irradiation was conducted simultaneously on identical frozen and nonfrozen samples (3 ml/ampoule) from the same culture. The results clearly indicate the decreased radiosensitivity of *E. coli* in the frozen state.

Effect of Food Medium

Because of the wide variety of organic materials present in foods, study is needed concerning the role these organic materials may play when foods are sterilized by ionizing radiations. Most of the chemical changes occurring during food irradiation can be ascribed to free radicals that arise from the decomposition of water. The materials present in complex natural substances such as foods might conceivably capture these free radicals, reduce their concentration, and therefore reduce the chemical changes ascribed to them. Hence, irradiation of a bacterial species in a food material was studied. Pea purée was inoculated with suspensions of *E. coli*, and 3-ml samples were sealed in ampoules under air and irradiated.

The survival curves obtained in these experiments are shown in Figs. 3 and 4. The air-reference-broth curves given in these two illustrations are based on data obtained with suspensions of *E. coli* prepared and irradiated at the same time as the pea-purée samples. For comparative purposes, the air-frozen-broth curves are reproduced from Figs. 1 and 2. Their corresponding air-reference-broth curves are also reproduced so differences in air reference can be seen.

Comparison of the survival curves of *E. coli* in saline and in nutrient-broth mediums under identical atmospheres (Fig. 1) shows the protective effect of the more complex nutrient-broth suspensions. The curves obtained for inoculated pea purée (Figs. 3 and 4) illustrate this protective effect of the medium even more strikingly. Moreover, for gamma rays the curves for pea purée show no break but pass through the zero-dose—100% survival origin.

In the cathode-ray experiments, the

survival curve for *E. coli* in pea purée crosses the curve for *E. coli* in frozen broth. The reason for this is not known at the present time. The frozen-broth curve cannot be extrapolated to the origin. True effective beta doses received by the frozen-broth samples might have been difficult to measure because of sample thickness effects (7). Therefore, the curves of the gamma experiments (Fig. 3) are considered to be more significant.

In the gamma-ray experiments (Fig. 3), the air-pea purée and air-frozen-broth curves are almost coincident if differences in slopes of the corresponding air-reference curves are taken into account. This result would tend to support the idea that the semisolid state of pea purée may inhibit diffusion of free radicals analogous to the effect noted with frozen media.

Conclusion

Figures 1–4 allow comparison of *E. coli* survival under different irradiation and suspension conditions. These comparisons demonstrate that the suspension's composition, its physical state, and the atmosphere above it are important in determining the radiosensitivity of this organism.

Of interest in the food field is the evidence that oxygen consumption by food material can occur during irradiation at a rate greater than normal.

The implications of these studies appear to be of such importance that similar studies are being conducted with spore-forming organisms, including species of food-spoilage origin.

* * *

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Methods and Equipment

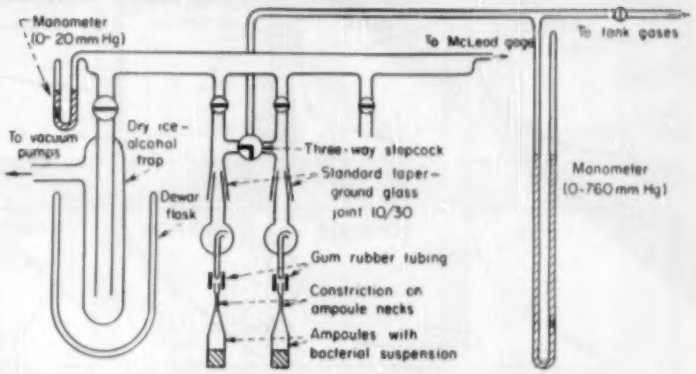

FIG. 5. Pyrex apparatus for evacuating and filling sample ampoules

The sources of ionizing radiation used included a kilocurie Co^{60} source and a 3-Mev Van de Graaff accelerator. These sources and their dosimetry have been described previously (1, 3–6). The microbiological methods for culture preparation, and quantitative evaluation of radiation lethality are standard routine procedures (7).

Bacterial suspensions were aseptically transferred by pipette to sterile 5-ml Kimble "neutraglas" ampoules for irradiation. Samples to be sealed in air were merely pipetted into the ampoules, which were then sealed by a cross-fire torch. Ampoules containing samples to be sealed under vacuum or under gas were filled with the bacterial suspension, then the necks of the ampoules were partially constricted. Then the ampoules were placed on a vacuum-gas line (Fig. 5), where they were aseptically evacuated.

Evacuation was accomplished by a single-stage mercury-vapor pump backed by a Cenco Hyvac mechanical pump. McLeod gage readings indicated a vacuum of 10^{-6} mm Hg, or better, in the closed system.

Before evacuation, the ampoules were cooled to 0° C with a slush of ice and water to avoid liquid loss. Pumping usually continued at least two minutes beyond hearing the pump's "high-vacuum click." The McLeod gage indicated vacuums of 10^{-5} mm Hg or better. However, the partial pressure of dissolved air left in the sample is believed to be greater. After evacuation, the ampoule neck was sealed with a cross-fire torch.

For the samples to be irradiated under atmospheres other than air, tanks of purified gases were attached so that gas introduction into the ampoule could be accomplished immediately after evacuation. Pressures were adjusted to about 700 mm Hg before sealing.

Because of the variety and number of experiments necessary to investigate chemical and physical factors affecting the radiosensitivity of microorganisms, several months were required for data collection. Over a period of months, variations might occur to alter apparent radiosensitivities, either because of changes in experimental technique caused by different assisting personnel, or by changes in the cultures themselves. Therefore, a technique was adopted that would allow valid comparisons between sets of results obtained at different times.

In each series of experiments involving a particular set of conditions, reference samples comprising from 25–50% of the total number were exposed simultaneously to doses equal to the doses received by the other samples. These reference samples were 3-ml broth suspensions of the bacteria sealed in an air atmosphere and are named "air-reference samples." A survival curve can be constructed for the air-reference samples, and the curve is then called the "air-reference curve" for the particular set of experimental conditions under study. Comparison of survival curves for two or more different sets of experimental conditions is then facilitated by comparison of the air-reference curves.

For economy of space, the data obtained are given in summary form only. Detailed descriptions of all the studies except those concerned with pea purée are in a previous report (6).

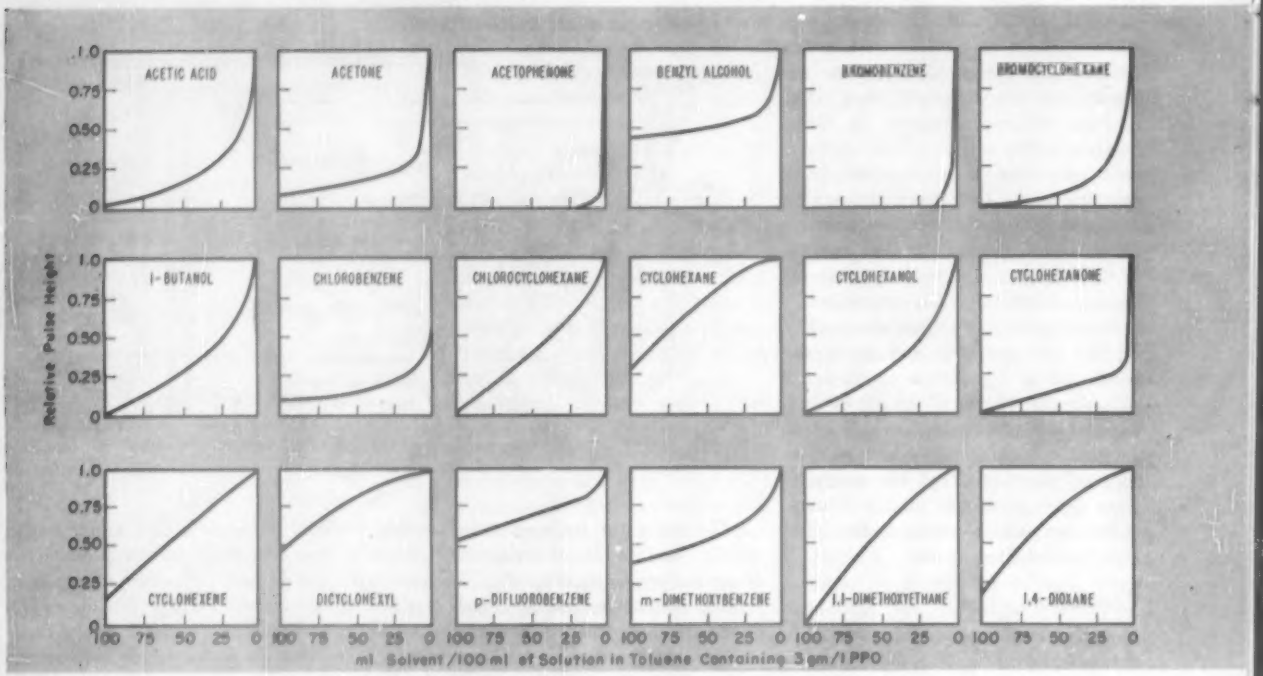

FIG. 1. Solvent concentration curves in toluene containing 3 gm PPO per liter

Importance of Solvent in Liquid Scintillators

Significance of the solvent was shown by measuring:

- **Photon mean-free-path in 44 solvents**
- **Relative pulse height of 2,5-diphenyloxazole solutions**
- **Effect of solute concentration on pulse-height peak**
- **Solvent concentration curves in toluene**

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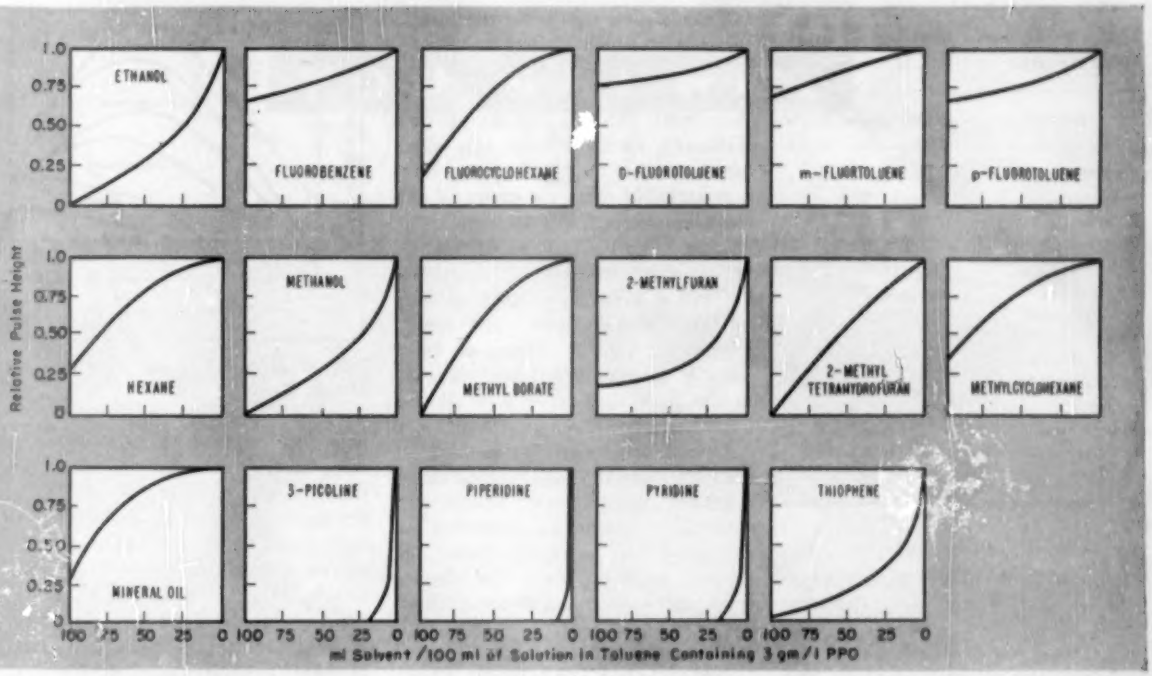
LIQUID SCINTILLATOR SOLVENTS have recently been gaining in prestige by being less and less the ignored 99% of the liquid-scintillation system.

A simple example serves to point out the solvent's role. A solution of a few grams of 2,5-diphenyloxazole (PPO) per liter of methanol completely fails to scintillate in the presence of ionizing radiation, but fluoresces well under ultraviolet excitation. The corresponding toluene solution both scintillates and fluoresces.

Ultraviolet lines, such as in the mercury arc, can directly excite PPO to a state necessary for light emission, rendering it inconsequential whether toluene or methanol molecules are present. But for the high energies in ionizing particles to result in solute excitation, suitable degradation and transfer mechanisms must be possible. The benzenoid resonance system offers these in a way that methanol cannot match.

In various applications, special characteristics may be demanded of the solvent:

1. Solubility requirements include ability to dissolve water samples for fast coincidence counting of tritium; this has been satisfied by ethanol-toluene mixtures (*1*). Liquid neutron



detectors using cadmium propionate require methanol and toluene (*2*). Where Lucite containers may be desired, the weak solvent power of phenylcyclohexane or triethylbenzene is advantageous. Future work on the incorporation of special high-Z elements may require efficient solvents with peculiar structures as yet unstudied.

2. Applications benefiting from high hydrogen density can use mineral oil or triethylbenzenes, which are, respectively, 56% and 26% richer in hydrogen than toluene.

3. Purification of solvents for small detector work is essential to insure removal of quenching impurities. The increasing popularity of giant detectors has emphasized the necessity for attaining a minimum in light absorption by the solvent. This requires a good choice of solvent, a useful method for its ultimate purification, and a secondary solute to produce photons with long mean free paths.

Experimental Results

In the first part of this study, purified solvents had their optical densities measured against ultrapure cyclohexane at various wavelengths in a 10-cm cell with a Beckman model DU

TABLE 1—Light Absorption in Scintillation Solvents

	Wavelength (Å) at which mean free path is				*Wavelength (Å) at which mean free path is*		
Solvent	*0.5 m*	*1.0 m*	*2.0 m*	*Solvent*	*0.5 m*	*1.0 m*	*2.0 m*
Acetic acid	<3,300	3,680	4,100	Fluorobenzene	3,400	3,470	3,520
Acetone	3,530	3,620	3,780	*o*-fluorotoluene	3,400	3,510	3,590
Acetophenone	4,160	4,290	4,470	*m*-fluorotoluene	3,380	3,540	3,650
Anisole	3,830	4,000	4,200	*p*-fluorotoluene	3,430	3,530	3,580
Benzene	3,460	3,580	3,700	Hexane	—	—	<3,300
Benzyl alcohol	3,790	3,900	4,020	Mesitylene	3,430	3,540	3,630
Bromobenzene	3,720	3,780	3,860	Methanol	—	<3,300	3,300
Bromocyclo-hexane	3,860	3,950	4,130	Methyl borate	—	<3,300	3,340
1-butanol	—	<3,300	3,510	2-methylfuran	3,890	4,070	4,240
n-butylbenzene	3,740	3,800	3,860	2-methyltetra-hydrofuran	3,530	3,630	3,730
Chlorobenzene	3,470	3,580	3,690	Methylcyclo-hexane	—	—	<3,300
Chlorocyclo-hexane	3,910	4,180	4,510	Mineral oil	3,440	3,620	3,900
Cumene	3,670	3,720	3,800	Phenylcyclohex-ane	3,600	3,690	3,780
Cyclohexene	3,710	3,780	3,830	3-picoline	3,410	3,460	3,540
p-cymene	3,750	3,800	3,850	Piperidine	3,950	4,220	4,330
Dicyclohexyl	3,580	3,660	3,730	Pyridine	3,570	3,700	3,930
m-dimethoxy-benzene	4,290	4,350	4,420	Thiophene	3,820	3,970	4,140
1,1-dimethoxy-ethane	3,420	3,500	3,620	Toluene	3,460	3,630	3,820
1,4-dioxane	3,460	3,510	3,560	Triethylbenzene	3,730	3,840	4,030
Ethylbenzene	3,590	3,700	3,800	Xylene	3,560	3,650	3,730
Fluorocyclo-hexane	3,800	4,040	4,640	*o*-xylene	3,640	3,770	3,900
				m-xylene	3,560	3,670	3,770
				p-xylene	3,590	3,670	3,740

TABLE 2—Solvents Allowing Greatest Pulse Heights

Solvent	*Relative pulse height*
p-xylene	1.12
m-xylene	1.09
Xylene	1.07
Phenylcyclohexane	1.02
Toluene	1.00
o-xylene	0.98
Ethylbenzene	0.96
Triethylbenzene	0.96
n-butylbenzene	0.88
Benzene	0.85
Anisole	0.83
Mesitylene	0.82
Cumene	0.80
p-cymene	0.80

ultraviolet spectrophotometer. The results listed in Table 1 indicate wavelengths at which photon mean free paths are ½, 1, and 2 meters.

Relative-pulse-height measurements have been run with 49 solvents. The emitting solute was PPO at a fixed concentration of 3 gm/liter, except in six representative solute concentration curves discussed later. An 8-4 type Du Mont 6292 photomultiplier (No. 553-6692W) (*3*) and an aluminum reflector were used. The Cs^{137} internal-conversion electron line was analyzed in each measurement and related to the result from a standard 3 gm/l PPO solution in toluene.

Table 2 gives results for the best 12 solvents of which all but anisole are alkylbenzenes; the other solvents gave relative-pulse-height figures of less than 0.80. This is consistent with Kallman's excellent work (*4*), which has shown that the alkylbenzenes form a remarkably exclusive group of efficient liquid-scintillator solvents.

More information was obtained about other solvents by measuring the full concentration range of their mixtures with toluene. The results appear in Fig. 1. Many of these solvents are so poor that measurements in the pure state gave zero relative pulse height.

This toluene-solution method of evaluation showed cases having either a gradual drop in pulse height with decreasing toluene concentration or an abrupt fall off with considerable toluene still present. The former type can be described as a "diluter" and the latter as a "quencher." Diluters include alcohols, olefins, saturated hydrocarbons, ethers, fluoro- and chloroalkanes and methyl borate. Quenchers include ketones, chloro- and bromobenzene, amines and thiophene.

The five fluoroaromatic compounds tested form a group of solvents between one-half and three-quarters as efficient as toluene. Dicyclohexyl, with a 0.48 relative pulse height, is the best of the nonaromatic solvents.

Six pure solvents had their curves of PPO concentration vs relative pulse height determined (Fig. 2), showing some dissimilar solvent effects on peak pulse height and self-quenching of the solute. The peaks of these curves were found to be at about 6 gm/l for toluene and fluorobenzene, 7 gm/l for anisole, 11 gm/l for dicyclohexyl, and greater than 60 gm/l for mineral oil and cyclohexene. The last two measurements were terminated upon arrival at the saturated solutions.

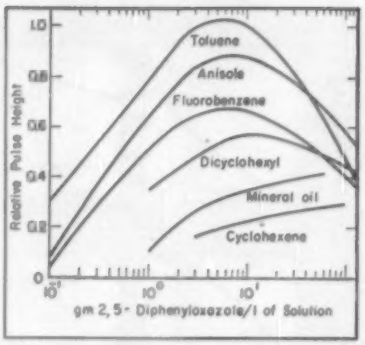


FIG. 2. Effect of solvent on PPO pulse height

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

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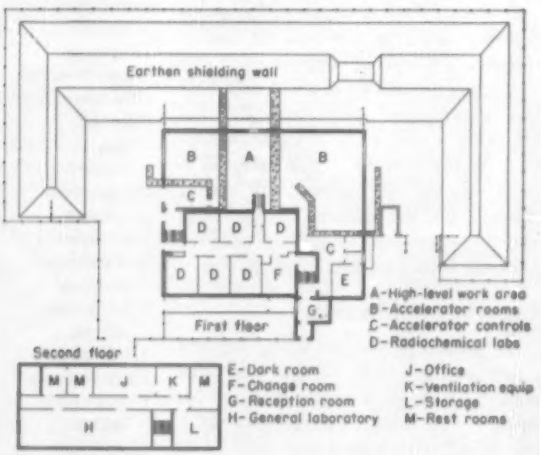
New Industrial Radiation Laboratory Completed by GE

12-FT EARTHEN WALL provides shielding around three sides of General Electric's new radiation lab at Schenectady, N. Y. Lab, costing about $300,000 to convert from a factory building, will be used for studies of activation analysis, tracers, accelerators, radiation effects, and instrumentation. Equipment includes: 15-Mev betatron, 500-kev cascade accelerator, and 1,000-c Co^{60} source



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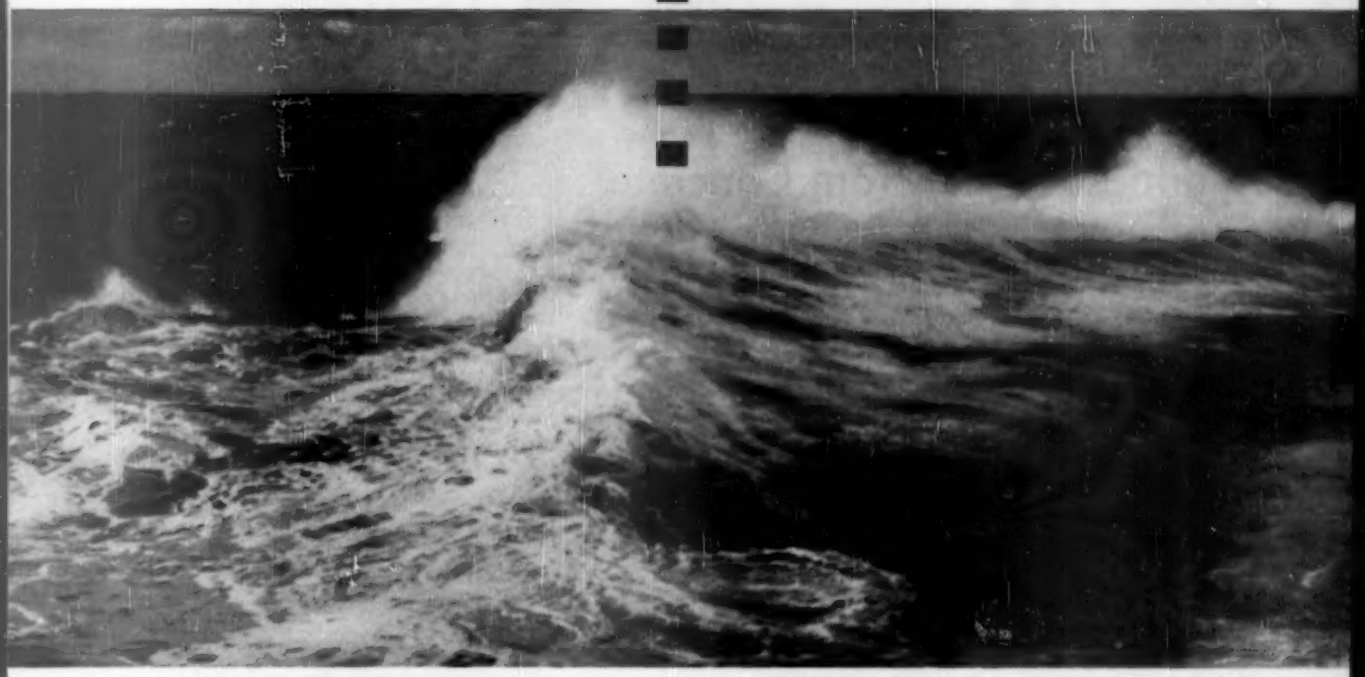

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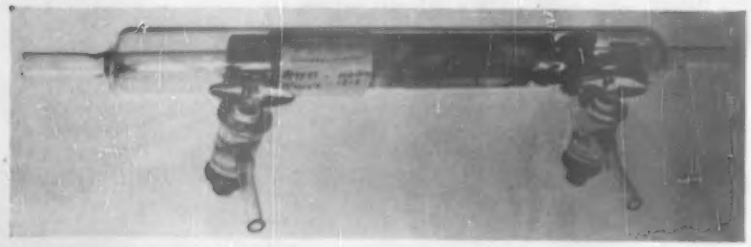


CONCRETE SAMPLE enclosed in glass tube

Radon Released from Concrete in Radiant Heating

By A. F. GABRYSH and F. J. DAVIS
Oak Ridge National Laboratory
Oak Ridge, Tennessee

The results of the experiments reported here indicate that building material having an average uranium concentration of 0.004% and higher should be avoided in structures for human habitation.

In mining for uranium and radium ore, "low-grade" rock is deposited on the surface and frequently used in concrete mixtures. If these mixtures are used in constructing walls and floors, especially where the building is warmed by heating the floors or walls, the radon leakage is increased by gas diffusion* through microfissures. These fissures, which at low temperatures seem to act as closed chambers, expand and open up when the concrete is heated.

A sample container was designed to determine the radon leakage of heated concrete (see illustration). The specimen used in the sample mixture, Chattanooga black shale, is known to have a relatively high radium content. Taken from the upper unit (perhaps 2 ft below bottom of Maury) in Jackson County, Tenn., it was selected because it was relatively fresh yet weathered enough to have typical "recently-deposited" characteristics. Absence of plant spores in the specimen indicated that the measured radioactivity was due to minerals in the natural rock and not to "carrier" sediments lodged in the spores.

The shale was ground to pass a 100-mesh sieve. Concrete containing two parts crushed shale and three parts mortar was molded around a glass tube ⅜ in., i.d., and 14 in. long. After aging 30 days (limitations—ASTM designations C87 and C109—on material passing a No. 100 sieve is that the fine-aggregate mortar develop a required compressive strength in 28 days), it was enclosed in a larger-diameter 11-in.-long tube whose ends were sealed to the walls of the smaller tube. Two stopcocks were sealed at each end of the outermost cylinder. Sample 1 (see table) remained sealed for about 31 days (time for maximum radon concentration, i.e., for radium-radon equilibrium) or longer; for sample 2, runs were made after remaining sealed for shorter periods.

Radon-α counts were made on the unheated and heated (by running hot water through inner tube) samples with an ion chamber.*

Using data obtained for sample 2 (see table), we can calculate the air contamination by radon of a particular room made of this concrete mixture—bearing in mind that deposited rocks from a uranium mine would more likely be of a higher grade. The sample shale had an average uranium concentration of 0.008%.†

For the first two runs, there is a difference of 58×10^{-12} curies between unheated and heated sample; this gives approximately 15.25×10^{-12} curies/in^3 increase due to heating. The volume of a heated concrete floor 15 ft × 10 ft × 3 in. is 64,800 in^3; about 10^{-6} curies of radon would be released. Assuming that 5.0×10^{-7} curies diffuse into an 8-ft-high room (34,000 liters of air), then the air contains 1.5×10^{-11} curies of radon per liter. If the room were located between two heated floors, the concentration would be about 3×10^{-11} curies of radon/liter for this shale. In the phosphate-rock region of Florida, homes have been built from material now known to have a concentration of 0.02% uranium; thus, for these structures, 3×10^{-11} curies/liter would be increased by a factor of about 3.

A calculation using the sample 2 data indicates that the total radon released is $2.87 \times 10^{-10}/0.58 \times 10^{-10}$ or about 5 times that due to heating alone. Therefore, if the room were tightly closed for 30 days, the maximum radon content in the air could be about $5(3 \times 10^{-11})$ or 1.5×10^{-10} curies of radon per liter.

* * *

We wish to express our thanks to R. M. Richardson, U. S. Geological Survey, Knoxville, Tenn., and the Dept. of Geology, University of Tennessee, for supplying the shale sample and its history.

* George L. Bate, Dept. of Geology, Columbia University, private communication.

* The complete analyzing procedure can be obtained from the authors.

† Analysis made by the Geology Dept., University of Tennessee.

Radon Measurements Made on Concrete Containing Chattanooga Black Shale

Sample and volume	*Run*	*Temp. (°F)*	*Counting time (hr)*	*Net count per hour*	*Curies for total aggregate volume*
No. 1	1	68	12	55,746	2.96×10^{-10}
4.3 in^3	2	137	12	72,000	3.75×10^{-10}
No. 2	1	75	12	40,241	2.29×10^{-10}
3.8 in^3	2	136.4	12	50,000	2.87×10^{-10}
	3	72	12	39,839	2.11×10^{-10}
	4	140.7	12	58,625	3.03×10^{-10}

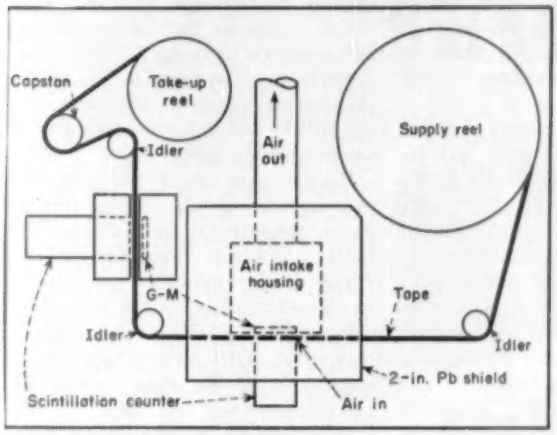


FIG. 1. Top layout of air monitor

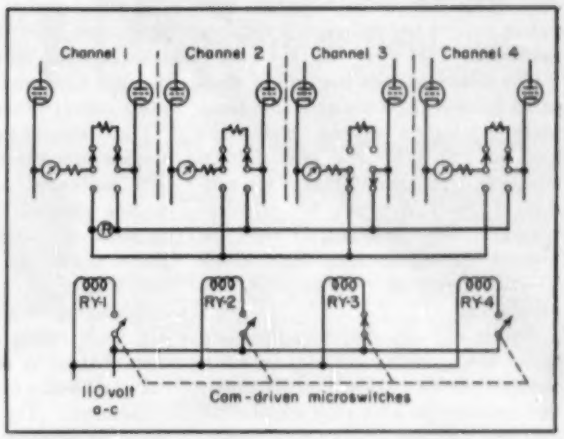


FIG. 2. Recorder multiplexing system

Monitor Measures Air and Surface Contamination

By H. V. WATTS, A. R. BRAUNER, G. M. BURGWALD, and L. REIFFEL
Armour Research Foundation, Illinois Institute of Technology, Chicago, Illinois

To provide instrumentation for routine and after-spill monitoring of laboratory air and for checking surface contamination, a relatively compact unit has been constructed capable of providing complete monitoring facilities for a radioisotope laboratory of moderate size.

The monitor, with its air-collection system, detectors, and electronic circuitry, continuously records intensities of the beta-gamma component and the alpha component of the air sample collected by passing laboratory air through a continuously moving filter tape. It automatically provides data at collection time and after a preselected 7–12-hr delay. Thus, short-lived activities always present in the atmosphere can be eliminated, thereby minimizing interference when measurements of long-lived artificial activity are important.

The monitor is equipped with two hand-held probes—one for beta-gamma surface contamination and the other for alpha surface contamination. These probes can be switched into the electronic circuitry and recorder. Ordinarily, when the probes are not in use, all tape-counting channels are presented on a single strip-chart recorder by means of a multiplexing switch. An alarm circuit triggered at any preset level is connected with each prompt counting channel.

To aid calibration, a 60-cps pulse generator is built into the unit. Alternating current from the power transformer fires a neon bulb and an *RC* circuit differentiates the waveform giving positive and negative pulses. The unused positive pulses are eliminated by a diode rectifier.

The over-all dimensions of the unit are 26¼ × 22½ × 44 in., not including the handles on the sides or the double blower mounted on the rear to cool the electronic equipment. Swivel casters make the unit mobile.

Air collection. Figure 1 shows the general layout of the air-collection and detector portions of the monitor. A heavy-duty positive blower connected for vacuum-pump operation moves 3 ft³/min of air so that particles are continuously collected on a 2.24-in² portion of the high-efficiency filter tape* moving 1 in./hr across the air-intake housing. A synchronous motor geared to the capstan moves the 3-in.-wide filter.

The air flow rate is indicated by a water manometer calibrated with a

* H-70-grade, Hollingsworth and Vose Company, E. Walpole, Mass.

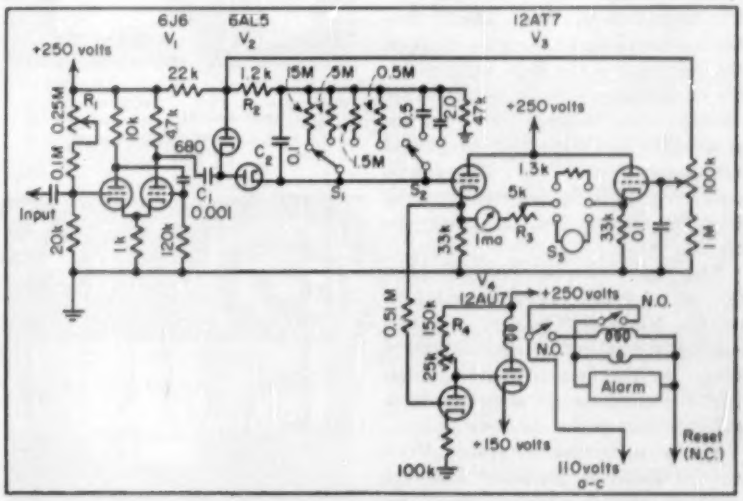


FIG. 3. Counting-rate meter circuit diagram

flowmeter. Noise is reduced by undercoating on the unit's side and rear panels and by two automobile exhaust mufflers.

The collection area is a grid of staggered holes drilled through a thin brass plate in a square pattern; its effective area is 2.24 in². The grid pattern covers an area equal to that of the window of the G-M tube. For practical purposes, the filter tape, which is treated with silicone resin that renders it water-repellent, is essentially an absolute filter.

Detectors. Six detectors are used with the monitor. Two detectors monitor particles on the filter promptly, two monitor the filter after an interval, and two are hand-held surface probes.

Two of the four detectors monitoring the filter tape are mica-end-window Anton-1001T G-M counters. Their flat "pancake" shapes offer the advantage of large-diameter windows without large volume and resulting high background. These tubes are used in beta-gamma counting channels. The other two detectors are alpha scintillation counters, each consisting of a deposited layer of silver-activated zinc sulfide on the face of an RCA-6199 photomultiplier tube. Each tube is housed in a brass cylinder with a thin sheet of aluminum foil, 0.3 mg/cm², at the window end. They are on the "upstream" side of the tape since the filters' low penetrability tends to trap most of the sample near this surface.

One pair of detectors is mounted directly in line with the air intake to give a prompt indication of changes in radioactive content of the air. The G-M tube is placed inside the air-intake housing, which is shielded with 2 in. of lead on all sides. The air flow has not been found to have an effect on the operation of the G-M tube, which has its thin mica window facing the air stream. The "delayed" detectors are mounted in lead bricks that tend to aid one another in shielding. They can be positioned to give delayed counting rate information 7–12 hr after the initial survey.

The continuous drive of the filter tape makes the average air sample seen by the "prompt" pair of detectors equivalent to about a 30-min collection time. At the delayed-counting position, the same sample area includes a full collection period of about 1 hr.

The two surface-survey probes, which can be switched manually into the counting-rate circuitry of the "delayed" pair of detectors, use slightly different detectors. The G-M counter uses an Anton-201T end-window tube. The alpha probe uses the RCA-5819 photomultiplier tube. An audible counting-rate indication is available through a loudspeaker switchable into either survey-probe channel.

Four similar ratemeter channels operate simultaneously, each with its own calibrated meter. For data-recording purposes, a strip-chart milliammeter is used. A manual switch allows any of the four channels to be individually plotted or provides for multiplexing of all four channels (see Fig. 2). During multiplex operation, each channel is recorded for 7.5 min out of a 30-min cycling time.

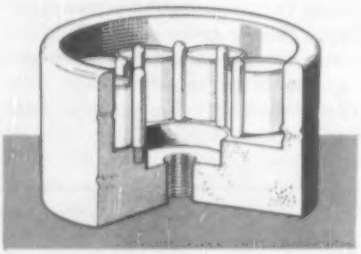
Circuitry. The circuitry for one of the counting-rate channels is shown in Fig. 3. Negative pulses from the scintillation or G-M counters actuate the monostable multivibrator circuit V_1. Pulses from the trigger pair drive a linear step-charger circuit so that the d-c output voltage of the step-charger is proportional to the input pulse rate. Capacitors are charged and discharged through the diode V_2.

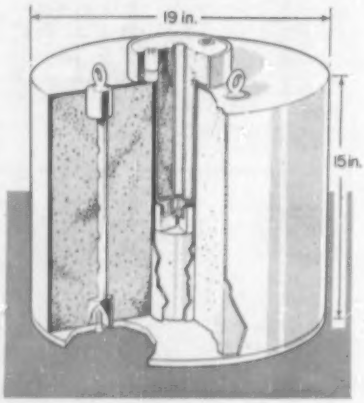
The voltage developed at the output of the step-charger is measured with the vacuum-tube voltmeter V_3. Prompt channels are equipped with alarm circuits so that an abnormally high radiation intensity will sound the alarm horn. The signal for the alarm circuit is taken from the left cathode of the VTVM and is direct-coupled to a two-stage d-c amplifier V_4.

High voltage for all four detectors and the two probes is obtained from a 60-cps supply controlled by two CK-1039, 1,200-volt regulator tubes. Three divider networks are placed across each regulator output so that the voltage on each counter can be adjusted separately. Each high-voltage output is decoupled so that there is no interference between channels. Since photomultipliers vary in gain over wide limits, it is necessary to adjust the high voltage so that the alpha pulse heights are the same for all counters. A plot of discriminator setting vs cpm was taken to determine the best operating point. The G-M counters are operated in the middle of their plateaus.

* * *

The expert assistance of H. Deptolla and L. Perrin in constructing the mechanical portions of the instrument is gratefully acknowledged.





COBALT-60 SOURCES, in light-alloy tray (top), are loaded into lead-filled container

The Little Hotspot

Miniature Co^{60} Gamma Irradiator

By W. S. EASTWOOD
Isotope Division
Harwell, England

In the design of cylindrical gamma-radiation sources, a compromise must be made between the size of object to be accommodated within the cylinder and the dose rate. Published designs of cobalt-60 irradiators have internal diameters between 1¾ in. (*1*) and 6½ in. (*2*), giving dose rates of 100,000 to 500,000 rep/hr. Since the doses to produce interesting effects are usually in the region of a million roentgens, we consider that the specimen volume could be profitably reduced so as to increase the dose rate.

The cobalt sources available were metal cylinders 12 × 12 mm diameter, each about 55 effective curies (4π ionization measurements based on 13.5

r/hr/mc at 1 cm). These are individually capsuled in aluminum, making their dimensions nearly 14 mm.

Calculations made for different numbers of these sources arranged in a ring led us to adopt a single ring of eight sources. This pattern gives a central space of 13-mm diameter. The cobalt sources are held in a light alloy tray that is then loaded into a lead-filled container having 8-in. wall thickness (see illustration).

A central lead plug with a ¾-in.-diameter hole permits specimens to be lowered into the center of the cobalt ring. The sources cannot be "seen" through this hole so that only scattered radiation emerges. A spiral heating element with woven-glass insulation can surround the specimen if irradiations at temperatures up to 100° C are required.

The first model has been in use now for several months. Total activity is 439 curies; the dose rate measured by ferrous-ferric methods gave 1.6×10^6 rep/hr. Radiation appears reasonably uniform over an axial length of 2 cm. A quick estimation of this was made by filling a glass tube with an alkali halide and noting the uniformity of color induced in the salt.

Outside the container, the radiation dose is quite small except for a narrow beam upwards that is of softer quality than the gammas from Co^{60}. The side dose is 0.4 mr/min: the top surface is 2 mr/min, while the beam from the open hole at 1 ft above the top is 116 mr/min. Normally the hole is covered by a 4-in. lead brick and the specimen is lowered on a wire keeping the hands away from the vertical beam.

The sacrifice in radiated volume gives a dose rate about three times higher than other irradiators of this type. At the same time specimens of 2 cm^3 appear to be enough to enable our chemists to analyze the effects of the radiation. The unit is so compact that it can be kept in a corner of the laboratory without special buildings being erected. The container could be made up by any university workshop. For American users there is a ready supply of capsuled cylinders of 1-cm diameter and about 70 curies each available from Oak Ridge (*3*). If these sources were used, the wall thickness of lead might well be increased to 9 in.

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FIG. 1. Bakelite-mounted sample just removed from collodion, drying on absorbent paper

Wet-Process Autoradiography Modified for Studying Metals

By GEORGE C. TOWE,* HENRY J. GOMBERG,† and J. W. FREEMAN
Engineering Research Institute, University of Michigan, Ann Arbor, Michigan

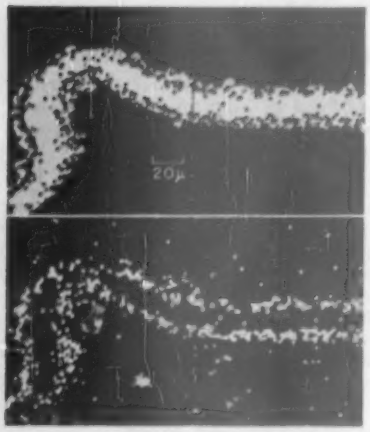

FIG. 2. Wet-process autoradiograph (2-hr exposure) of Ni^{63} sample; (top) bright-field vertical illumination, (bottom) polarized illumination showing only developed silver grains

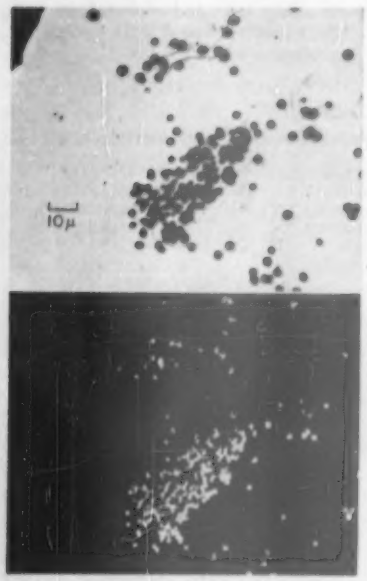

FIG. 3. Wet-process autoradiograph (4.5-hr exposure) of C^{14} in iron with (top) bright and (bottom) polarized illumination

Since the wet-process autoradiographic technique was first described in 1951 (*1*), it has been the subject of further investigation with two main objectives: (a) improved resolution and (b) metallurgical applications. Radioactive metal specimens were used as standard samples in this work; however, biological tissue sections and many other sample types can also be suitably prepared for wet-process autoradiography.

The best procedure established during this investigation for preparing wet-process autoradiographs is as follows:

1. Mount the metallographic specimens (radioactive sample and a control) in Bakelite cured at 150° C under >5,000 lb/in² pressure. Flats ground into the mount facilitate handling with tongs (Fig. 1). The mounted sample should be given a good metallographic polish, being careful to keep the surface flat with a minimum of rounding at the edges. All of the etchant must be removed by thorough washing, and the mount must be left clean and dry.

2. Apply a protective Vinylite layer by dipping the mount into a 2% solution of VYNS in methyl ethyl ketone for a few seconds. Drain and dry the sample for a few minutes in an upright position on a paper towel. Heat for 30–50 min 6 in. from a 250-watt heat lamp, cool to room temperature, and transfer to a desiccator to await autoradiography.

3. In a darkroom with dull-red illumination, immerse the sample for a few seconds in the cold collodion solution (2° C). Place mount upright on an absorbent paper towel for 30 sec to drain the excess collodion solution

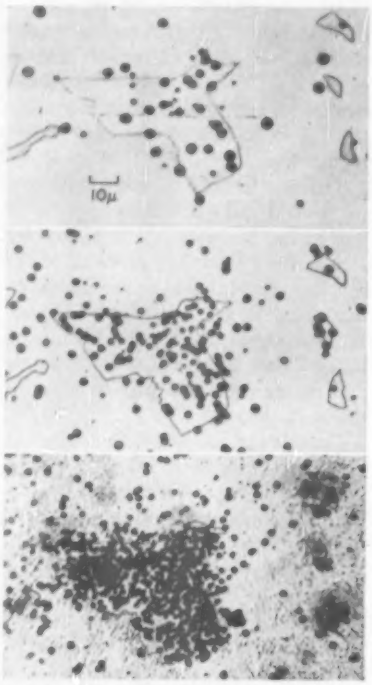

FIG. 4. Wet-process autoradiographs of same Fe_3C crystal at (top) 32-min, (center) 95-min, and (bottom) 285-min exposures

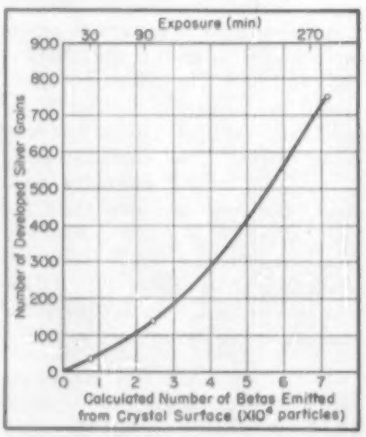

FIG. 5. Wet-process autoradiography sensitivity curve

* PRESENT ADDRESS: Scientific Laboratory, Ford Motor Company, Dearborn, Michigan.

† PRESENT ADDRESS: Michigan Memorial-Phoenix Project, University of Michigan.

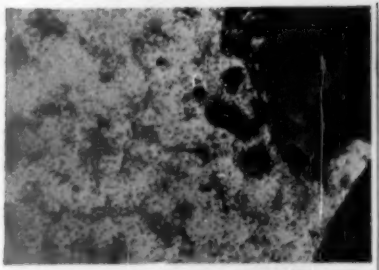

FIG. 6. Corrosion of steel surface from failure of Vinylite layer shown on wet-process autoradiograph

and to set the collodion film on the mount.

In processing, the Bakelite mounts should be handled with forceps as shown in Fig. 1. They are gripped at the side so that the collodion film on the specimen face is not disturbed.

4. Immerse the mount immediately into the cold silver nitrate solution, keeping it dark and cold (approximately 2° C). Several mounts can be exposed in the same solution since the range of beta particles in water seldom exceeds several millimeters.

5. After a suitable exposure (generally several hours), the sample is placed carefully in a fresh developing solution at room temperature (approximately 20° C) for 20 sec. Do not stir or agitate during development.

6. Remove the sample from the developing solution and place in the

Wet-Autoradiography Solutions

Vinylite

VYNS Vinylite—2 gm; Methyl ethyl ketone—100 ml

Collodion

U.S.P. collodion—8 ml; Absolute ethyl alcohol—42 ml; Cadmium bromide ($CdBr_2{\cdot}4H_2O$)—0.75 gm; Ammonium bromide (NH_4Br)—0.15 gm

Silver nitrate

Silver nitrate ($AgNO_3$)—25 gm; Distilled water—250 ml; Sulfuric acid—add to nitrate solution to 2.5 pH (about 0.31 ml of 10% by volume sulfuric acid)

Developer

Ferrous sulfate ($FeSO_4{\cdot}7H_2O$)—4 gm; Distilled water—100 ml

Fixing solution

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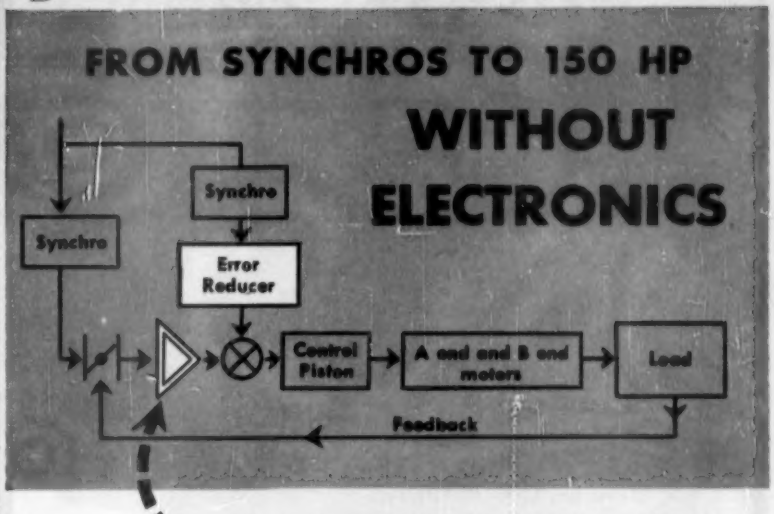

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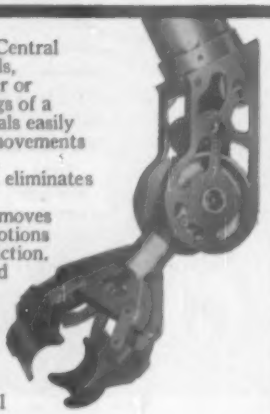

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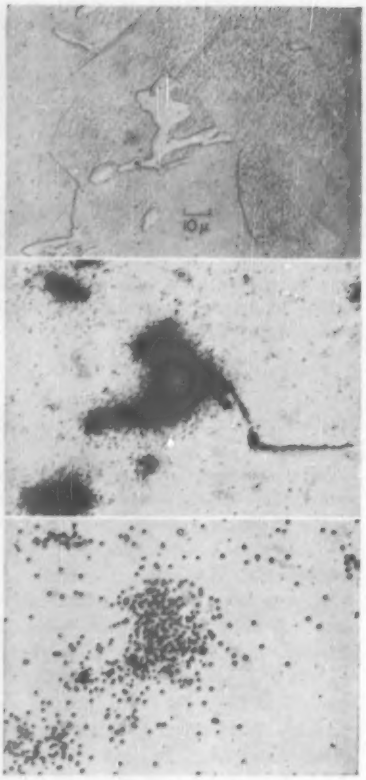

FIG. 7. Resolution obtainable with C^{14}-carburized steel: (top) microstructure, picral etch; (center) 9-hr exposure with Kodak autoradiographic permeable-base stripping film; (bottom) 6½-hr exposure wet-process autoradiograph. Resolution of two autoradiograph methods is approximately the same, since sensitive layer in each case is 5 microns thick applied over 1 micron of Vinylite

fixing solution for 45–60 sec at room temperature.

7. Wash by immersing in distilled water for 10–20 sec to remove soluble salts and dry in a gentle air stream.

The specimen is now ready for microscopic examination.

Results

The soft beta radiation from nickel-63 was particularly suitable for determining the resolution limit of the wet-process technique. A platinum foil approximately 15 microns thick was electroplated with radioactive nickel. The nickel was in turn plated with silver to reduce side scatter of the beta particles through the Bakelite mounting material. A cross section of this sample appeared as a Ag-Ni-Pt-Ni-Ag sandwich. Figure 2 is an autoradiograph of this specimen. The resolution indicated by this sample is better than 10 microns. The exposure

time for this autoradiograph was 2 hr.

Iron and steel samples containing carbon-14 were also prepared as standard specimens for studying the autoradiography. The radioactive carbon is segregated in iron carbide (Fe_3C) islands in a matrix of alpha iron containing very little dissolved carbon. Figure 3 is an autoradiograph exposed for 4.5 hr of this type of sample. The autoradiographic image correlates very well with the Fe_3C microstructure.

Figure 4 is a series of three autoradiographs taken at the same field for varying exposure times. Two interesting features of wet-process autoradiography are demonstrated. First it is observed that as the silver grain population increases, the silver grain size decreases (from 3 microns at top to 1 micron at bottom). Second, by counting the silver grains associated with the large carbide, it was possible to prepare the plot shown in Fig. 5. This figure readily indicates the nonlinearity of the photographic process, an effect thoroughly discussed from a theoretical approach by Gomberg (*1, 2*). The efficiency of the radiation-sensitive layer appears to increase with longer exposures.

The measured surface beta activity of the carbon-14 carburized steel samples was approximately 3×10^6 cpm/cm^2. These samples produce suitable autoradiographs with exposures of 30–60 min. Thus the required beta ac-

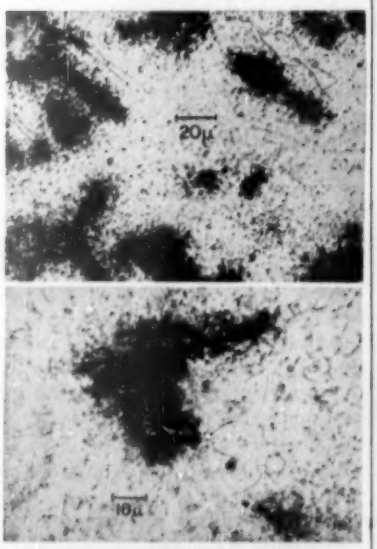

FIG. 8. Kodak stripping film autoradiographs showing (top) 20-micron displacement after exposure and (bottom) reticulation in gelatine film as well as 25-micron displacement

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tivity is near 10^6 counts/cm² for the exposure.

A Vinylite layer is applied to the samples to protect the metals from being attacked by the photographic solution. Unfortunately the thin layers (approximately 1 micron) required for high resolution studies will not protect steel samples for periods much longer than 24 hr. Figure 6 shows an example of corrosion on a steel surface resulting from failure of the Vinylite layer. Thicker plastic protective layers can be applied, but only to the detriment of high-resolution autoradiography.

Stripping Film

The Eastman Kodak product designated "Kodak Autoradiographic Permeable Base Stripping Film (Experimental)" was investigated as a sample of one of the best (highest resolution) commercial emulsions suitable for autoradiography. Figure 7 shows bare etched metal, stripping film autoradiograph, and wet-process autoradiograph of a given field of the carbon-14 steel.

Perhaps the most unfortunate characteristics encountered in the use of stripping film is the tendency to pucker, buckle, or displace relative to the metal. Evidence of this is seen in Fig. 8.

* * *

This note is based on the dissertation presented by George C. Tows as part of the requirements for the degree Doctor of Philosophy at the University of Michigan. The work was sponsored by the National Advisory Committee for Aeronautics and the U. S. Atomic Energy Commission. Additional information will be published in the N.A.C.A. Technical Note No. 3209.

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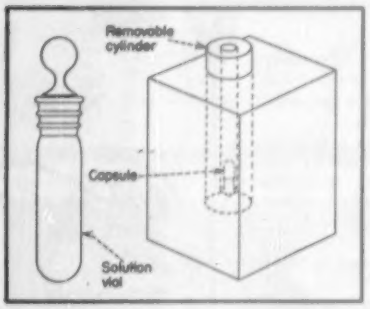

FIG. 1. Phantocube phantom consists of Lucite or Plexiglas cube and cylindrical capsule holder replaceable with vial

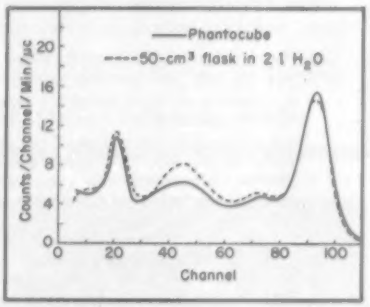

FIG. 2. Energy distributions of Phantocube and water phantom obtained with pulse-height analyzer and $\frac{1}{32}$-in. lead filter

Use of I-131 Capsules in Thyroid-Uptake Studies

By D. L. TABERN and ROBERT H. STOREY
Department of Radioactive Pharmaceuticals, Abbott Laboratories, North Chicago, Illinois

Diagnostic radioiodide-uptake studies on the human thyroid have been justly called one of the most accurate diagnostic tests in use today.

Recently the Isotope Division of the Atomic Energy Commission has broadened the scope of diagnostic radioiodide use, making it available to clinics and to properly trained and qualified physicians for use in their private practices.

Such expansion of radioiodine use into a routine diagnostic test beyond the supervision of the radiologist and the hospital committee makes doubly desirable further simplifications of technique, if this can be accomplished at no sacrifice of accuracy. J. W. Lewis has proposed just such a simplification (*1*) based upon a direct comparison in a phantom of a solution equivalent to that taken by the patient, and the thyroid itself, readings being made on a ratemeter directly in percentage uptake. As an added check, the "standard solution" is transferred to a two-quart milk container and compared with the total urinary output under identical conditions of geometry. This procedure, while avoiding decay corrections and other calculations, involves the handling and pipetting of radioactive solutions and the use of twice the dose received by the patient for each determination. Also, two detecting devices are employed, one to cover the thyroid and the phantom and the other the much larger volume of solutions involved in urine intercomparisons.

The use of capsules of radioiodide had originally been suggested by Libby (*2*), but his capsules were filled with a fine radioactive powder that poses a definite contamination hazard, both in the laboratory and at the point of use.

We have found a much simpler, hazard-free solution to the problem by adsorbing the almost unweighable amount of completely reduced iodide activity, corresponding in properties to U.S.P. standards, on the interior wall of a special opaque gelatin capsule that is then tightly sealed.* This can be handled without fear of spillage or contamination. A single capsule may be given, in a sealed, appropriately labeled vial, to be taken at home or in the patient's room at a time that permits the 12, 24 or 48 hr uptake to be carried out on the hospital schedule. By having the capsule taken at 7 A.M., 4, 6, and 8 hr uptake measurements give added value to the tests.

A uniformity of filling from capsule to capsule has been achieved equal or superior to that of the usual solution measurement in the laboratory, with variation usually less than $\pm 2\%$. It is not only unnecessary to measure the activity of individual capsules, but any single capsule becomes a reliable standard for that lot, and remains so as long as that lot is used. Capsules containing 50, 25 and 15 μc have been found to meet almost all needs.

Animal and clinical studies have shown that the capsules, having no coating, disintegrate promptly in the gastrointestinal tract, and obviously can be dissolved rapidly in warm water whenever desired for the preparation of solutions.

The availability of such readily soluble capsules opens another possibility, namely the avoidance of all solutions

* Radiocap, trademark of Abbott Laboratories.

in thyroid-uptake studies. This has been achieved through the development of several phantoms that permit quantitative comparison of the relative "point" source of the capsule with the much larger area of the thyroid or the urine sample.

A number of recent publications have emphasized the importance of "back scattering" in making accurate measurements on iodine in body tissues. Allen (*3*) has indicated that in brain tumor studies the scattered low-energy radiations may considerably exceed the direct primary rays. In the case of the thyroid, the amount is less, but may run as high as 25–30%. In the past, effort has largely been directed toward the simulation of the thyroid and surrounding anatomical structures through the making of large water, wood or plastic phantoms. A theoretically more correct, but quite costly, method is the use of an "electronic gate" to pass only the 0.364-Mev main gamma band of I^{131}.

In practice, as was suggested by Seed (*4*) several years ago, and more recently stressed by Hine (*5*) *et al.*, essentially the same result may be achieved by the use of a thin lead filter over the window of the detecting tube. There is, of course, some decrease in the counts observed, but these losses represent, for the most part, the weak-energy secondary radiation derived from surrounding tissues, with only a moderate decrease in the 0.364-Mev primaries from the thyroid. With the advent of scintillation tubes of good crystal size giving 500–1,000 counts/μc/min at 30 cm, this loss is relatively immaterial, still permitting counting times of 1–4 min over the thyroid. The use of such a lead filter also nullifies variations from one scaler to another due to differences in gate settings in the input circuits of the various instruments, permitting better intercomparison in results obtained in various laboratories, and with different instruments in the same laboratory.

It has been our obvious desire to devise a system applicable to all of the assay equipment now in use or projected for the immediate future. In these studies, we have had available through the courtesy of the manufacturers eight different detectors varying all the way from the standard TGC 2, TGC 8 and bismuth-cathode tubes to several "preproduction" models of large crystal scintillators.

Distances of 20–50 cm between the sensitive volume of the crystal and "source" activities ranging from 1 to

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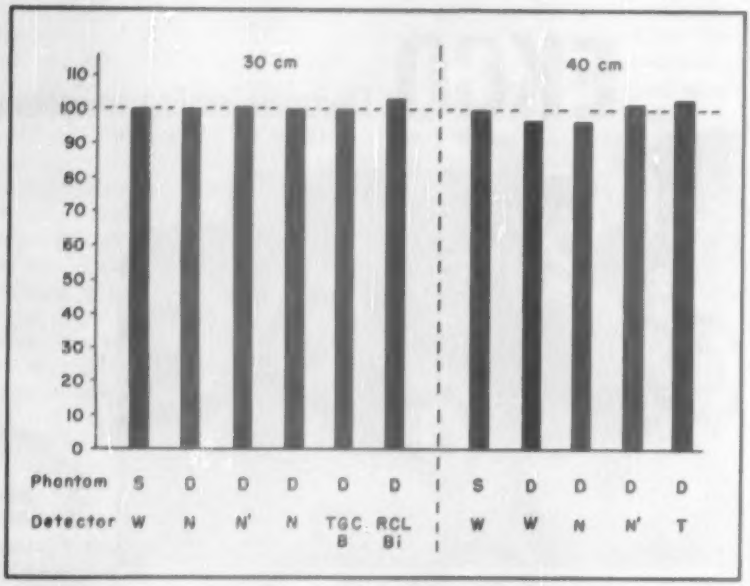

FIG. 3. Comparison of Phantocube (D) and water phantom (S) measurements, using various counting systems and distances with 1/16-in. lead filter

50, or more μc have been routinely, measured. The expected straight-line relationships were observed.

Since the absolute activity in the human thyroid is difficult to determine, we have prepared an actual cast of an average-sized head, neck and shoulders, which was then filled with paraffin, and a "window" cut in the cast material over the thyroid area. Suitable "ports" permit the introduction into this, in positions resembling that of the thyroid, of varying amounts of I^{131} activity. As an actual "working" model, capable of more exact distance measurements, we have adopted—as Lewis, Hine, *et al.*, have done—a 50-cm^3 volumetric flask of activity, in a 2-liter beaker of water at 1 cm from the front of the beaker. Under these conditions, the center of radioactivity is approximately 3.5 cm from the front of the beaker. That Lewis finds his values for thyroid plus urine to approximate the average dose gives added validity to this assumption. Hine *et al.* find that the energy distribution of such a system also approximates that from the "average" human case. "Reference" solutions were prepared from Radiocaps of the same lot, which had been assayed by both β and γ counting. For the other phantoms, the capsules were simply placed without dissolving in a suitable Lucite "test tube," which could be placed in a fixed position. In all, some nine different phantoms were constructed and carefully studied.

It was obviously necessary to know the amounts of primary and secondary radiations from the phantoms of greatest interest. These values were determined by first measuring the capsule attached to Scotch tape, and suspended in air, and then with a 1/2-in. cube of lead placed directly in front of it to remove a known high percentage of the primaries (δ). Essentially the same arrangement was then made inside the phantom. Briefly, the scattered radiation was usually 20–30% of the total. With this same equipment plus suitable thin lead filters, it was possible to show that 1/32 in. of lead removed 92% of these secondaries and 1/16 in. removed 97%.

Rather to our surprise, a simple plastic (Plexiglas or Lucite) cube 6 cm × 6 cm × 9 cm with the capsule 3.5 cm from the front face (the "Phantocube,"* see Fig. 1) gave within 15% of the same correction for both front absorption and back scatter as the older cumbersome water or the expensive large plastic counterparts. Since backscatter is some 20–30%, this represents an effective accuracy for the Phantocube alone of some 94–95% of total counts, and for the combination of lead filter plus the Phantom of better than 97%.

Through the kindness of Mr. Hugh Stoddard of Atomic Instrument Co., the energy distribution from the Phantocube and from the water phantom were plotted from data obtained on a twenty-channel pulse-height analyzer. As seen in Fig. 2, these are in excellent agreement. The same is indicated by Fig. 3 when the Phantocube (D) is intercompared with the water phantom (S) using a variety of detection equipment.

By constructing the Phantocube as shown in Fig. 1, the removable cylinder holding the capsule may be replaced by a stoppered test tube or vial of appropriate size, so that 7–10 cm^3 solutions may be measured under identical conditions of geometry, absorption, and backscattering. In other words, they too can be compared directly with the thyroid.

The measurement of urinary-I^{131} output can be a valuable additional aid in diagnosis. The usual half-pint, "lunch room," fiber milk carton has essentially the same size and shape as the Phantocube. An aliquot of the urine may be counted therein, and pro-

* Trademark, Abbott Laboratories.

Counting Tubes Used in Phantom Measurements

		cpm/μc at 30 cm	*Background*	*Symbol*
N. Wood Counter Lab.	1-in. dia. × 1-in. thick NaI crystal	600	200	W′
N. Wood Counter Lab.	1-in. dia. × 1/2-in. thick NaI crystal	475	175	W
Nuclear Instr. & Chem. Corp. (DS-1)	3/4-in. dia. × 3/4-in. thick NaI crystal	350	250	N
Tracerlab (P-20-M)	1-in. dia. × 1-in. thick NaI crystal	525		T
Tracerlab (TGC 8)	G-M tube	40	118	TGC 8
Radiation Counter Lab. (bismuth cathode)		75		Bi
Nuclear Instr. & Chem. Corp. (Mediac)	1 1/2-in. dia. × 1-in. thick NaI crystal	1,075	250	N′
Tracerlab (TGC 2)	G-M tube	15	60	TGC 2

viding the center of activity is at the same point as the Radiocap, observed counts are the same. Experiments using amounts present in various clinical situations show that the total activities accounted for usually run between 98 and 102%.

The bismuth-cathode tube, while very reliable, is likewise energy dependent, and, as the above, needs a $\frac{1}{32}$-in. lead filter. This results in a reduction of observed counts to the point where tube-to-sample distances greater than 30 cm result in unduly long counting times.

The TGC 8, because of the heavy tube wall, is less energy dependent, and our results indicate that it may be used directly with most of the phantoms studied. However, here also counting rates are only 10% of those obtainable with a high-grade scintillation unit. The TGC 2 and 3 are obviously too gamma insensitive for this purpose.

Since, in office and clinic use, it is not usually possible to operate in an isolated area, and since scintillation tubes are notoriously sensitive to background, the tube should be well shielded by $\frac{1}{32}$ in. of lead, not only over the crystal but also well back thereof. This, of necessity, decreases the maneuverability of the system and calls for a well designed tube stand. There are many advantages to constructing the tube plus shield for mounting on a table or cart, and placing the patient on or in an adjustable chair or bed.

In general, data showed greatest uniformity and reproducibility at a distance of 30 cm from the sensitive center of the crystal to the active source, though 40 cm is also satisfactory. At these distances, errors in estimating the location are minimized. By measuring at both distances, and checking from the graph that the inverse-square law applies, individual reading errors can be caught and an estimate made of thyroid depth.

Obviously, while there should be good shielding in front of the tube, the collimation may well be conical to provide for the uniform coverage of an area somewhat greater than the area of the thyroid and phantom, namely a circle 12–13 cm in diameter.

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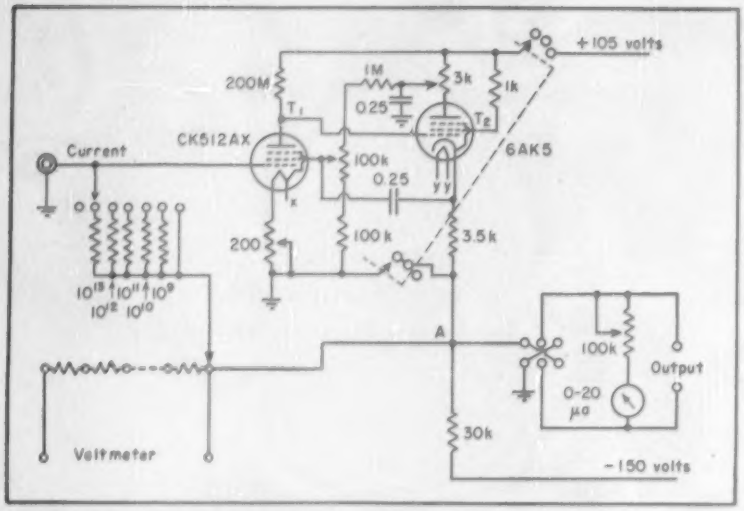

TWO-STAGE small-current d-c amplifier. For necessary regulation, 105-volt supply has OB2 regulator across output, −150-volt has OA2. Filament of T_1 is powered from 105-volt supply via suitable dropping resistor. Heater for T_2 is kept positive to minimize 60-cycle modulation of output

Small-Current D-C Amplifier

By G. F. ZINDLER and NEWTON UNDERWOOD
Physics Department
North Carolina State College of Agriculture and Engineering University of North Carolina
Raleigh, North Carolina

A reliable small-current d-c amplifier was developed with a readily usable full-scale sensitivity of 10^{-12} ampere. Good stability has been achieved by using 100% negative feedback, which makes performance less dependent on the tube characteristics (*1–5*).

With care, this instrument provides a full-scale sensitivity of 10^{-13} ampere. The zero stability, with no signal input, was checked by a recorder over a 12-hr period on the 10^{-12}-ampere range and was within ± 10 mv when operated from an unregulated 110-volt a-c line.

The amplifier is basically a two-stage circuit (see diagram) using a subminiature pentode (CK512AX) as the input tube that drives another pentode (6AK5) as the output tube. Direct coupling is used between the two stages. The input grid, operated at ground potential, has 100% d-c negative feedback applied to it. Transient negative feedback is also incorporated, which maintains the negative feedback characteristics under transient signal conditions. Positive feedback is used to increase the loop gain of the amplifier. The higher amplifier gain improves the response. The negative feedback point in the amplifier is grounded to protect the meter and to eliminate any large voltage surge across the input resistor and insulator as the instrument is initially switched on.

When there is no input signal, the circuit parameters are so chosen that the potential at point A (see illustration) is zero volts with respect to ground. The input grid is also at zero volts if the grid current is negligible.

The rise in the grid voltage developed by the input current across the input resistor causes an increased plate current to flow through the input tube T_1. The increased plate current flowing through the plate-load resistor causes a larger voltage drop across the resistor, thus lowering the potential of the T_1 plate as well as the T_2 grid. The output circuit is a cathode follower with the cathode resistance returned to −150 volts rather than ground. As the T_2 grid potential drops, the plate current through the tube is reduced, which lowers the potential of the cathode and also point A. This change in current is the amplifier current output; output is therefore the product of the current output and the amplifier output resistance and opposite in polarity to the voltage developed across the input resistor.

The 100% d-c negative feedback contributes improved linearity of response and effective reduction in input resistance, which provides a reduced input time constant. Since the negative feedback is frequency dependent because of the shunt-input capacitance, additional transient negative feedback is applied to the input-tube screen grid through the capacitor from the output-tube cathode (see illustration). Since the CK512AX screen grid has effective plate-current controlling characteristics, reducing the screen potential reduces the plate current in the same manner, but to a lesser extent, as reducing the control-grid potential.

D-C positive feedback increases the amplifier voltage gain by a factor of three or more. The quiescent screen potential of the input tube is obtained through a voltage divider network from the plate potential of the output tube. Since a small plate-load resistor is used with the output tube, its plate potential changes in opposite phase to the signal on its grid and therefore in the same phase relationship as the input signal to the amplifier. Thus the input-tube screen-grid potential is shifted, due to this positive feedback, in the same phase relationship as the input grid; thus, the plate current of the tube responds as though a larger input signal had been applied.

One of the major problems in the design of small-current amplifiers is to make the effects of current drawn by the input grid negligible. In this instrument, the operating conditions for minimum grid current (*6*) are determined in the following way. The tube is installed in a test circuit where the plate and screen voltages are easily adjusted and the plate current can be measured. The control grid is allowed to float. A light-tight electrostatic shield around the tube prevents photoelectric effects and external electric fields affecting the control grid. When the various potentials are applied, the floating grid seeks a quiescent potential. This potential on the grid is due to a negative charge build up that becomes steady at a point where the number of electrons reaching the grid, against its retarding field, equals the number of electrons being lost to positive gas ions (*7*) and leakage currents. The net grid current is then close to zero. By measuring the plate current, the screen and plate voltages can be adjusted to provide desirable operating parameters while maintaining zero grid current. Retaining these plate and screen voltages, the control grid is connected to an adjustable bias source. The bias is adjusted to reproduce the

plate current observed with the grid floating; this bias is then used in the amplifier operation. This is an important and somewhat critical adjustment. As one precaution, if the CK512AX is cleaned and silicone treated, moisture will not collect to diminish the high resistance qualities of the glass. On a group of CK512AX tubes tested, the bias necessary for zero grid current was −2.0 to −2.2 volts with 10–14 volts on the screen and plate. The loop gain of the amplifier determines how closely the grid is held to the point of minimum grid current over the span of the amplifier.

A 100-megohm input resistance d-c voltmeter is incorporated with the amplifier. The voltmeter function is obtained by introducing the unknown voltage into the circuit in the same way as a current input signal produces an input voltage. A constant-input-resistance voltage-divider network provides a standard 0–1 volt signal to the amplifier regardless of the voltmeter range being used.

The amplifier proper is entirely enclosed in a separate aluminum box, providing complete shielding from the power supply and other external objects. The box is light-tight to reduce the photoelectric release of electrons within the CK512AX, which can produce erroneous readings on the more sensitive current ranges.

The amplifier is used to measure small d-c currents from high-impedance sources, such as photocells and ion chambers. With an ion chamber of 300-cm³ sensitive volume, 1.25×10^{-12} ampere was obtained from a standard 10,012-cpm alpha source. Since the input grid operates within 5 mv of ground potential, guard-electrode techniques can be applied to the input cable and within the ion chamber proper.

The output stage of the amplifier is capable of driving a 0–1 ma recorder. With a 1-ma output load, the maximum linear output span is reduced from ±7 volts with the 20-μa meter alone to ±2.5 volts. However, the output span used is ±1 volt and therefore well within this linear range.

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Producing Radioisotopes in Very Low Power Reactors

By A. A. JARRETT and S. BERGER
Nuclear Engineering and Manufacturing
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By producing short-lived isotopes as needed in a local, low-power reactor, the number of elements available for tracer studies is increased, the cost of handling and shipping large quantities of radioactive materials is reduced or eliminated, and disposal by decay becomes feasible. Isotopes producible in a 1-hr irradiation by a 1-watt nuclear reactor in sufficient specific activity for use in tracer experiments are listed in the table.

The table lists all radioisotopes that have half-lives greater than 10 min and specific activities greater than 10 dps/gm after 1-hr irradiation in a slow-neutron flux of 4×10^7 n/cm²/sec. Of the 100 radioisotopes produced, 70 have half-lives short enough for disposal by radioactive decay.

A reactor similar to North American Aviation's 1-watt Water Boiler Neutron Source (WBNS)* could be used. This reactor can provide a maximum slow-neutron flux of 4×10^7 n/cm²/sec for a specimen 15 cm long and 3 cm in diameter. Irradiation in a slow-neutron flux of 2×10^7 n/cm²/sec is possible for samples as large as $4 \times 4 \times 8$ in. The WBNS's fast neutron flux of 2×10^7 may make it suitable for fast-neutron reactions also.

This reactor's core is a 12-in. stainless-steel sphere with a 1-in. diam. hole through the center for use as an irradiation facility. Removable 4×4-in. graphite stringers near the core run through the 5-ft-diam. by 6-ft-high cylindrical graphite reflector to handle larger samples. This reactor can operate without refueling for more than 100 years with low radiation levels, no cooling, and little maintenance. Gaseous radioactive products accumulate safely inside the reactor core until removed at infrequent intervals.

* Described in *Science* **119**, No. 3079, (1954).

Radioisotopes Produced in One Hour by 1-Watt Reactor

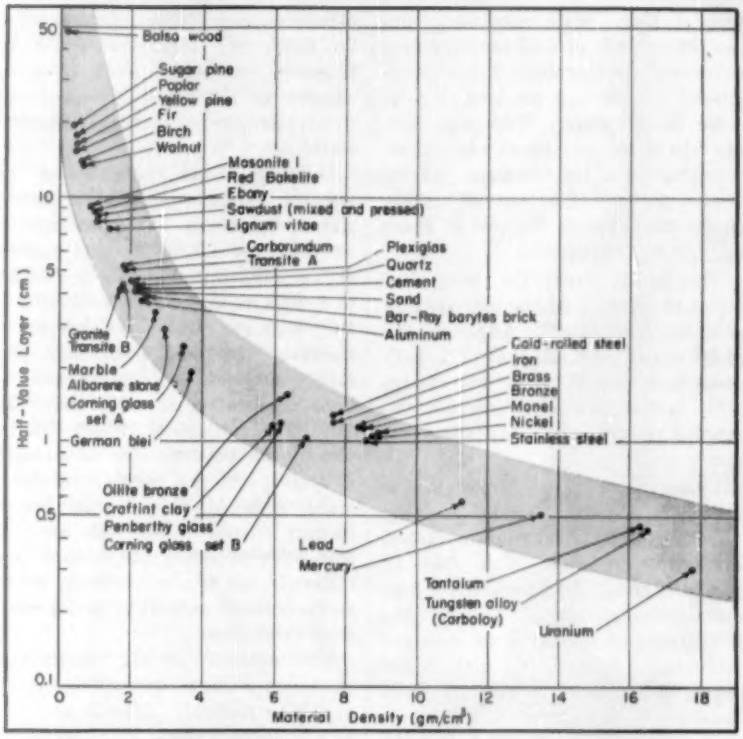
Isotope	*Half-life**	*Specific activity† (dps/gm)*	*Isotope*	*Half-life**	*Specific activity† (dps/gm)*	*Isotope*	*Half-life**	*Specific activity† (dps/gm)*
Na^{24}	15.0 h	25,000	Mo^{99}	67 h	120	Pm^{149}	47 h§	64
Si^{31}	2.6 h	700	Mo^{101}	15 m§	4,300	Pm^{151}	27 h§	3,400
P^{32}	14.5 d	300	Te^{101}	15 m§	3,500	Sm^{150}	47 h	94,000
S^{35}	87.1 d	25	Ru^{103}	41 d	62	Sm^{155}	25 m	170
Cl^{38}	37 m	64,000	Ru^{105}	4.5 h	4,000	Eu^{152}	9.2 h	8,000,000
A^{41}	1.83 h	120,000	Pd^{109}	13.2 h	36,000	Eu^{152}	5.3 y	2,800
K^{40}	1.2×10^9 y	110	Pd^{111}	26 m	9,200	Eu^{154}	5.3 y	1,200
K^{42}	12.4 h	2,400	Ag^{110}	270 d	33	Gd^{159}	18 h	5,900
Sc^{46}	85 d	6,600	Ag^{111}	7.5 d§	56	Tb^{160}	75 d	2,600
Cr^{51}	26.5 d	370	Cd^{115}	2.33 d	840	Dy^{165}	2.3 h	56,000,000
Mn^{56}	2.6 h	1,300,000	Cd^{117}	2.8 h	4,800	Ho^{166}	27 h	220,000
Co^{60}	5.2 y	190	In^{114}	50 d	300	Er^{171}	7.5 h	50,000
Co^{60}	10.7 m‡	17,000	In^{116}	54 m	16,000,000	Tm^{170}	129 d	3,800
Ni^{65}	2.5 h	2,100	In^{117}	1.9 h§	650	Yb^{169}	32 d	2,200
Cu^{64}	12.8 h	60,000	Sn^{121}	28 h	230	Yb^{175}	4.1 d	14,000
Zn^{65}	57 m	37,000	Sn^{123}	40 m	960	Yb^{177}	2.0 h	28,000
Zn^{69}	14 h	200	Sb^{122}	2.8 d	8,000	Lu^{176}	3.7 h	800,000
Ga^{70}	20.5 m	270,000	Sb^{124}	60 d	100	Lu^{177}	6.8 d§	67
Ga^{72}	14.2 h	23,000	Sb^{124}	21 m‡	2,200	Lu^{177}	6.8 d	56,000
Ge^{76}	82 m	28,000	Sn^{125}	10 m	2,300	Hf^{181}	46 d	300
Ge^{77}	12 h	280	Te^{127}	9.3 h	2,100	Ta^{182}	113 d	670
As^{76}	26.8 h	36,000	Te^{129}	72 m	2,600	W^{185}	77 d	32
Se^{81}	18 m	72,000	Te^{131}	25 m	11,000	W^{187}	24 h	38,000
Se^{81}	59 m‡	2,200	I^{128}	25 m	26	Re^{186}	90 h	37,000
Se^{83}	25 m	88	I^{131}	8 d§	1,100,000	Re^{188}	18 h	230,000
Br^{80}	18 m	1,300,000	Xe^{133}	5.3 d	55	Os^{191}	15 d	510
Br^{80}	4.4 h‡	72,000	Xe^{133}	2.3 d‡	3,300	Os^{193}	32 h	1,800
Br^{82}	35 h	6,700	Xe^{135}	9.2 h	4,800	Ir^{192}	70 d	19,000
Kr^{85}	4.4 h	2,400	Xe^{135}	15 m‡	1,600,000	Ir^{194}	19 h	360,000
Kr^{87}	78 m	1,200	Cs^{134}	2.3 y	160	Pt^{197}	18 h	55
Rb^{86}	19.5 d	220	Ba^{139}	85 m	24,000	Pt^{199}	31 m	26,000
Rb^{87}	6×10^{10} y	2,600	La^{140}	40 h	25,000	Au^{196}	2.7 d	130,000
Rb^{88}	17.8 m	8,100	Ce^{141}	28 d	48	Au^{199}	3.2 d§	140
Y^{90}	62 h	3,600	Ce^{143}	33 h	380	Hg^{197}	65 h	5,000
Zr^{97}	17 h§	84	Pr^{143}	19.3 h	67,000	Hg^{203}	44 d	70
Nb^{97}	72 m§	24	Nd^{147}	11 d	110	Th^{233}	23.5 m	640,000
			Nd^{149}	1.7 h	7,600	Pa^{233}	27.4 d	450
			Nd^{151}	12 m	170,000			

* Nuclear data from: Circular 499 (National Bureau of Standards, U. S. Department of Commerce, Washington, D. C., 1950); *Nuclear Science Abstracts* **7**, No. 24B (1953) and **8**, No. 6B (1954). Data continually is kept up-to-date by revisions published periodically in *Nuclear Science Abstracts*.

† Immediately after a 1-hr irradiation in a slow-neutron flux of 4×10^7 n/cm²/sec.

‡ Isomeric transition.

§ Result of two chain decays from lower Z parents.



HALF-VALUE LAYERS of various materials for 0.661-Mev gammas from Cs^{137}

Marble as a Radiation Shield

By MARSHALL BRUCER
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Marble is an effective shield against gamma radiation. When used to its best advantage, it may compete economically with other materials.

When low-energy radiation was the only kind available for medical use, lead always kept its preferred position as the shielding material of choice. It used up little space and was economical in that not much of it was required. With the rapid development of the use of higher-energy radiation and the necessity of thicker shielding walls, the argument about material cost versus effective use of space has become an important issue. Where a few inches of extra thickness makes no difference, marble is economically superior to lead. Where a few inches less space makes a big difference, marble may be economically superior to concrete.

Gamma Attenuation

In measuring the ability of any material to stop radiation, three factors must be considered: energy of the radiation, atomic mass of the material, and the material's density and uniformity.

For low-energy radiation, Table 1 shows that an element with a high atomic number such as lead (Z = 82), is much more effective than an element such as calcium (Z = 20), but the relative difference between calcium and lead becomes less as the energy increases. Lead is much better than calcium at low energies. It is not so much better at high energies.

At the energy of a low-voltage diagnostic X-ray machine, 71 in. of marble or 80-in. of concrete are necessary to give the same protection as 1 in. of lead. But at the high energy of

TABLE 1—Lead Equivalents of Marble and Concrete for X- and γ-Rays

Radiation energy	*Lead (11.3 gm/cm³)*	*Marble (2.69 gm/cm³)*	*Concrete (2.35 gm/cm³)*
75 Kev	1.0	71	80
150 Kev	1.0	67	75
200 Kev	1.0	58	65
300 Kev	1.0	25	28
400 Kev	1.0	16.5	18.5
0.661 Mev (Cs^{137})	1.0	5.74	6.80
1.25 Mev (Co^{60})	1.0	4.05	4.66

TABLE 2—How Marble Absorbs 0.661-Mev Gamma Rays from Cs^{137}

Marble	*Density (gm/cm³)*	*μ (cm⁻¹)*	*HVL (cm)*
Escalette	2.70	0.21	3.34
Blue Belge	2.67	0.19	3.63
Termain Domestic Fleuri	2.69	0.21	3.32
Alabama Veined A	2.68	0.21	3.35
Alabama Grade A	2.69	0.21	3.33
Etowah	2.70	0.21	3.32
Imperial Danby	2.69	0.21	3.35
Neshobe Gray	2.77	0.21	3.34
Rutland	2.70	0.21	3.33
Napoleon Gray	2.63	0.20	3.42
Ozark Tavernelle	2.63	0.21	3.37
Ozark Veined	2.70	0.21	3.33
Large Set Etowah	2.70	0.21	3.31
Alberene Soapstone	2.80	0.23	3.00

TABLE 3—How Materials Absorb 1.25-Mev Gammas from Co^{60}

Material	*Density (gm/cm³)*	*μ (cm⁻¹)*	*HVL (cm)*
Tungsten	16.50	0.92	0.75
Lead	11.26	0.64	1.09
Brass	8.40	0.43	1.62
Cold-rolled steel	7.76	0.40	1.75
High-density glass	6.94	0.37	1.86
Alberene soapstone	2.80	0.18	3.78
Typical marble	2.69	0.16	4.40
Berea sandstone	1.76	0.14	4.85
Aluminum	2.44	0.13	5.25
147-lb/ft³ concrete	2.35	0.13	5.41
Portland cement	2.12	0.12	5.88
Barytes stone brick	2.29	0.12	5.92
Sand	2.12	0.11	6.13
Water	1.00	0.06	10.83
Fir wood	0.53	0.03	22.58

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To be published Spring 1955 — probable price $12.50

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Co^{60} only about 4 in. of marble or 4¼ in. of concrete are equivalent to 1 inch of lead. Since only very thin protective walls of lead are necessary in low-voltage diagnostic X-ray installations, marble can be used, but at some disadvantage. With high-voltage teletherapy equipment where thick shielding walls are necessary, marble is in a position of advantage because of the difference in the cost of space and the cost of material.

The figure shows the half-value-layers of various building materials for gammas from Cs^{137}. Although the exact shape and slope of this half-value-layer:density plot will change with various radiation energies, the relative positions will stay about the same.

Density is of great importance in radiation shielding. It is the only essential difference between the various earth-type materials, since they all consist of about the same kinds of low-atomic-number atoms. One of the advantages of marble is its constant and reliable density. Concrete is not shown in the figure because concrete's density depends on the formula, how it is mixed, poured, tamped, and the presence of sizable holes to be expected in large pourings. Constant density is essential. Instead of concrete the graph shows sand and cement. When mixed, poured, and dried to a density of 2.35 gm/cm³, this commonly used 147-lb/ft³ concrete has a relative stopping power for high-energy gammas about 0.87 times that of marble.

Densities of marble from quarries ranging from Missouri to Vermont are shown in Table 2. Only four types differ by more than 1%, and different samples of the same marble showed remarkably constant densities. With this constant density, once a required thickness is determined, there is no necessity, as there is with concrete, to add a few inches for safety.

Table 3 and the figure compare the radiation-shielding characteristics of marble and other building and shielding materials. Marble stands in about the same position for shielding both 0.661-Mev and 1.25-Mev gammas. The differences are significant from the physical point of view, but the economic significance is not evident immediately from these facts alone.

The walls of a room in which a teletherapy machine is used must provide adequate shielding to nearby areas. Only a few inches of solid lead would be required, but this would be exceedingly expensive. If the teletherapy machine were being used for experimental irradiation of test animals no finish or cleanliness would be necessary, and about 20 in. of cheap concrete or a few feet of packed dirt would probably be the most economical shield.

However, when being used for treating patients, cleanliness and a certain minimum of appearance is essential. It might be that marble with a polished finish would be cheaper to construct, would reduce the size of the room less, would be cheaper to maintain and keep clean than any other material. By no means of least importance, it would have an attractive appearance, which can be one of the imponderable advantages in dealing with sick people. In a situation such as this, marble has a distinct advantage and can compete with other shielding and construction materials, not as a luxury item, but as an economical method of giving radiation protection.

The example of the teletherapy treatment room is not the only use of marble as a shield. After 2-years use as a temporary shield for radioisotope chemical preparation, marble bricks have shown less distortion of corners and edges than we have found in our standard lead bricks. They are used interchangeably with lead bricks and can be decontaminated more easily. The purchase order bids for lead and marble shielding bricks that would give about the same radiation protection showed that marble was ⅙ as expensive as lead. This is another example of the use of marble as a radiation shield that depends, not on the ancient recognition of marble as a beautiful and luxurious stone, but on the cold hard cash value of marble as a piece of equipment.

• • •

This article is based on a talk given before the Marble Institute of America, March 2, 1954, in Washington, D. C.

Work on which this article is based was performed under auspices of U. S. Atomic Energy Commission.

NUCLEAR POWER

• **Nautilus reactor's** deep-drawn stainless-steel container was completed recently by the Clark Grave Vault Co. of Columbus, Ohio. The container has gone through preliminary tests satisfactorily.

• **Thorium's** future as a fertile material was delineated by ORNL's A. M.

Weinberg in the December *Scientific American*.

He said, "As the AEC has announced, a thorium reactor can breed more fuel than it burns . . . this was probably the most important scientific announcement the Commission made in connection with the five-year program . . . .

"In the case of Pu, generated in a uranium reactor, the yield of thermal neutrons per fission is only two. This seems to rule out uranium as the raw material for a thermal breeder. The thermal-neutron yield from U^{233}, generated in a thorium reactor, is 'greater than two'. Consequently thorium is an attractive possibility as the basis of a thermal breeder . . .

"Neutron economy (of the PWR) can be greatly improved either by using heavy water instead of ordinary water or by replacing the uranium fuel with thorium and U^{233} . . .

"There appears to be no reason why thorium could not be used in the direct boiler design. In that case, this reactor (EBWR) might come close to breeding, especially if the moderator-coolant were heavy water."

• **Radioactivity** from Co^{60} formed by the irradiation of cobalt eroded from Stellite-tipped turbine blades is believed to be a potential maintenance problem on turbines used with boiling-water reactors. It seems highly probable that substitutes can be developed for the Stellite now used on tips of low-pressure turbine buckets. If a 200-Mw boiling reactor were operated for several years with low-cobalt-content turbine blades, then typical activities near the turbine after a 1-day cooling period probably would be about 1 mr/hr. If a 1-cm^3 hole occurred in a fuel element, the turbine activity might be as much as 5 mr/hr, which would still be well below "human tolerance" level. In these calculations, it was assumed that the water in the reactor would be filtered and deionized at the rate of 200 gal/min, and it was conservatively estimated that the steam entrained 1/1,000 as much radioactivity per gram as contained in the water in the reactor.

It is expected that Allis-Chalmers Mfg. Co., which is responsible for the power portion of the EBWR (NU, '54, p. 122), will avoid using turbine blades containing cobalt. Metal surfaces are to be of a material to which contamination will not adhere. Thus, after 1-day's cooling and a flushing operation, the turbine will be accessible for maintenance.

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TECHNICAL ADVANCES

Bragg-Gray Limitations

Care needs to be taken in the interpretation of results obtained with small metal-walled ionization chambers. Recent experiments by F. H. Attix of the National Bureau of Standards demonstrate that ionization in the chamber will not always be proportional to that in the wall. This is so even if the cavity is small compared with the range of secondary electrons, as required by the Bragg-Gray principle, according to a talk presented at a recent meeting of the American Physical Society.

New theory, by L. V. Spencer of NBS, shows that delta rays account for the effect. These energetic knock-on electrons produced by the passage of the secondary electrons through the wall, have not been properly accounted for in previous theories. Effects are complicated and can be substantial, especially in extrapolation chambers.

Air-walled chambers with air filling are not affected by these considerations because their equilibrium depends on more fundamental considerations of the chemical similarity of wall and filling gas.

Livermore's Huge Vacuum Vessel

A record-breaking vacuum tank, 60 feet in diameter and 87 feet long, was constructed to house the super-sized Materials Testing Accelerator. The huge container, built for the California Research and Development Company, included a 20-foot-diameter door that could pass a truck carrying construction materials. Operating pressure of 10^{-6} mm was obtained with forty-eight 32-in. diffusion pumps. Liquid nitrogen consumption was 15 tons daily in 60 traps. This Mark I accelerator has since been dismantled.

Technetium-98

Technetium is an unusual element having no stable isotopes. Technetium-98 is perhaps the least well understood of its 12 listed unstable isotopes, and has not been unequivocally identified. It is often erroneously assigned a 42-min half-life, but this is a confusion with Tc^{94}. A 2.7-day half life is sometimes assigned, but this is a confusion with Mo^{99}. Actually, since it is an odd-odd isotope, you would expect its spin to be large and its lifetime long—maybe so long that its specific activity would defy detection. Alperovitch and Miller of Columbia U. have used neutron activation of ores likely to contain technetium, hoping to find 6-hr Tc^{99m} from neutron capture in Tc^{98}. Results are still tentative, but may indicate that some Tc^{98} was there. Incidental mystery: technetium, vanishingly rare on earth, is observed in the absorption spectra of S-type pulsating red-giant stars with an abundance comparable with those of titanium and zirconium.

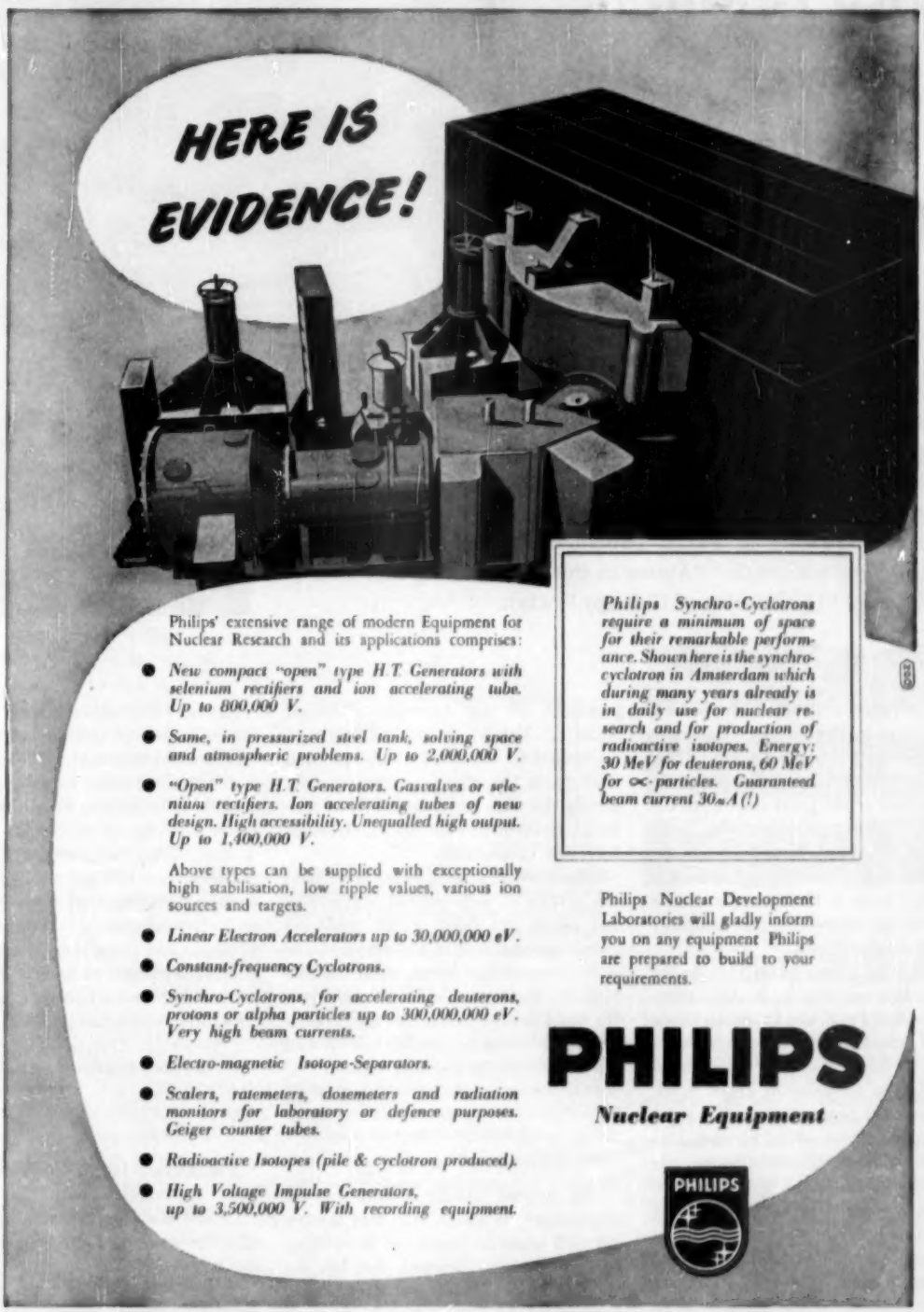
Synergistic Effects

Lethal effects of two radioisotopes internally administered can be greater than the sum of their effects taken singly. When the isotopes affect the same organs principally, the effects are likely to be additive. But when the organs affected are different, the net effects may be enhanced.

Supporting this, Western Reserve researchers Salerno and Friedell report that Au^{198} and Sr^{89} administered jointly was five times as lethal to rats as would be expected from their effects separately. Bone-seeking Sr^{89} destroys blood-producing ability, but the spleen can compensate for this by stimulating the marrow. However, colloidal Au^{198} is deposited principally in liver and spleen, thus injuring capacity to recover from Sr^{89}'s damage to bone marrow. Hypothesis is confirmed by synergism of blood-damaging X-rays and Au^{198}.

Radiation Degrades Dacron

Recent experiments by Audrey Todd in England confirm that reactor irradiation degrades Dacron, thus weakening it. (British call Dacron Terylene, film form is called Mylar, chemical name is polyethylene terephthalate.) Measurement of solution viscosities in *o*-chlorophenol revealed that chains break, although some branching may be present. This confirms earlier experiments elsewhere that showed powdering and embrittlement of samples irradiated with 1.5×10^{18} n/cm^2.



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Enrico Fermi:
Architect of the Atomic Age

There is little question that Enrico Fermi earned the title—architect of the atomic age. Rather than merely repeat the details of his outstanding achievements, the Editors of NUCLEONICS prefer to present a picture of Fermi, the man. The statements below, by people who knew him well, speak for themselves. In addition, we strongly recommend the warm, revealing biography of Fermi published by his wife, Laura, shortly before his death—"Atoms in the Family—My Life with Enrico Fermi" (University of Chicago Press).

Enrico Fermi was one of those rare personalities in the history of physics whose gifts included great talents both for theory and for experiment. As such, he was of the great line of Archimedes, Galileo, Newton, Benjamin Franklin, and Heinrich Hertz, men who arise hardly more than once in a century. Such is the measure of the great loss to science in the untimely death of Enrico Fermi.

In the brief fifteen years that he resided in this country he became thoroughly imbued with the American idiom and the American system of values and outlook on life. A superb teacher and a fascinating lecturer on every level, from the most elementary to the most abstract, he leaves behind him a generation of brilliant students who are enriching the scientific life of Europe and America. None who came under his influence will forget his extraordinary charm, his balance and objectivity of judgment, his modesty and, above all, the crystal clarity of his thought on all matters to which he directed his attention. He was a man who seemed almost incapable of error.

Fermi's quiet and modest nature caused him to shrink from public and administrative duties. It was with difficulty that he was persuaded to be president of the American Physical Society. Yet when the call came he responded to the need of his adopted country in the atomic energy project during the war, and later when he rendered notable service on the General Advisory Committee.

Like most great men of science Fermi was a man of deep ethical convictions and never lost sight of the profound moral implications in the employment of the tremendous forces which his discoveries made available to mankind. He was a man of peace, but the necessities of our times turned his talents and his discoveries to the arts of war.

—I. I. RABI
Higgins Professor of Physics
Columbia University, New York

The eternal scholar, Fermi was always eager to learn. He was always grateful when he found out something new. What he learned, he felt he should enrich. Having enriched what he learned, he felt he should teach it to others. Thus he prepared the fertile ground out of which arose the new solutions, the new ideas which kept the subject bright, fresh, and exciting.

—HERBERT ANDERSON
Institute for Nuclear Studies
University of Chicago

Actually the Institute is *his* Institute for he is its outstanding source of intellectual stimulation. It was Enrico who attended every seminar, and with incredible brilliance, critically essayed every new idea or discovery.

It was Enrico who arrived first in the morning and left last at night, filling each day with his outpouring of mental and physical energy. It was Enrico's presence and calm judgement and the enormous respect we had for him which made it impossible to even mention any small differences among us.

—SAMUEL K. ALLISON
Director, Institute for Nuclear Studies
University of Chicago

For Enrico Fermi, physics was almost synonomous with life, and the man and the scientist were one. Any effort to separate them would be futile and irreverent.

In all of the work of his early period we find his personal scientific style already fully developed. Really brilliant ideas are developed with such apparent simplicity of theoretical means that the results seemed to flow without effort.

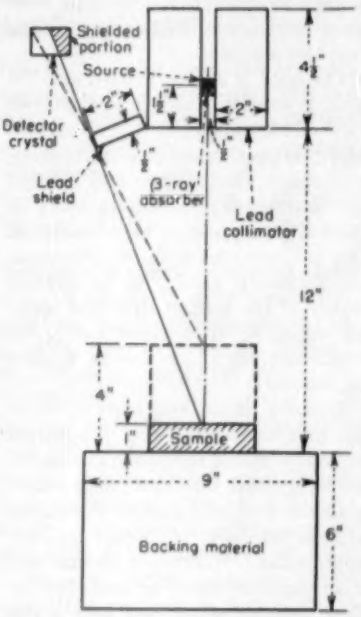
—EMILIO SEGRÈ
University of California, Berkeley

INDUSTRIAL APPLICATIONS

Gamma Scattering to Sort Coal from Shale Reducing the amount of feed to the conventional costly flotation process for separating lumps of coal and shale can be achieved by using backscattering of thulium-170 0.085-Mev γ-rays for primary sorting.* Basis of method (see figure) is fact that with a 6-in. thick graphite backing to produce saturation backscattering, coal lumps would produce no change in backscattered gamma radiation, but shale would cause a noticeable decrease. Conversely, with 6 in. of aluminum as backing, shale would have no effect on backscattering, but coal would cause an increase in backscattered radiation. Sorting system contemplated would use aluminum backing to select good coal, and graphite backing to reject shale, while middlings pass on to flotation process. Possibly, one source with two collimators could be used for both sortings.

Preliminary studies to develop separation system used graphite to simulate coal and aluminum to simulate shale. Closeness of atomic numbers of aluminum and shale allows this, as scattering and absorption of gamma rays is strongly dependent on atomic number.

Economic drawback at present is the large 5-curie source needed to make sample inspection time short (⅓ sec). Improvements in present scintillation detection system may make it possible to use a 1-curie source. Another possibility of lowering costs is using 1.7-year europium-155 as source, rather than 127-day thulium. But europium-155 is not yet available in sufficient quantity. Atomic Energy of Canada, Ltd., however, does list the isotope in its catalog of isotopes available from the Chalk River reactor.



COAL, SHALE SORTING uses this counting arrangement. Lead shield decreases detector crystal area that "sees" sample face, as distance between the two decreases, making counting rate independent of sample thickness

* J. L. Putman, E. W. Solomon, AERE-I/R-1407 (1954).

High-Energy Low-Weight Battery More delivered energy per unit weight than any other type of battery—that's the claim Tracerlab makes for its newly developed unit using a radioisotope ionization source. Developed for U. S. Army Signal Corps, battery has two metals of different work functions separated by a gap containing tritium and other gases. It develops 1,000 μμa at 1.7 volts in its present form; cells can be stacked to yield 100 volts. Interest is in "one-shot" applications, where long buildup time between discharges is not a disadvantage.

Beer Pasteurization Irradiation of packaged beer with 50,000 rep of Co^{60} gamma rays inactivates the yeast cells, resulting in complete biological stability, Neil F. Ritchey, atomic energy advisor to the Reynolds Metal Co., recently reported. Because glass bottles darken and enamel inside steel cans is adversely affected, aluminum cans would be most suitable for beer irradiation, it was stated. Cost and production rates appear attractive, but off-character odor and taste is developed in the beer by pasteurization doses. Independent study by J. D. Cronyn and coworkers at John Labatt Ltd., Canada, confirmed the dose needed for pasteurization.

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BOOKS

Introduction to Nuclear Engineering

By RAYMOND L. MURRAY (Prentice-Hall, Inc., New York, 1954, xiii + 418 pages, $9.35). Reviewed by CLARKE WILLIAMS, Nuclear Engineering Dept., Brookhaven National Laboratory, Upton, N. Y.

This book is based on the lectures given as part of the curriculum in Nuclear Engineering at the University of North Carolina. In it the author has attempted to touch on all the various elements leading to, arising from, and involving controlled chain fission reactions. The first three chapters are a brief survey of the physics leading up to and involved in a chain reaction. After a discussion of isotope separation, the concept of neutron economy is introduced as applicable to plutonium production. A catalog of reactors is then given that illustrates different methods of classification. The factors that appear in the "four factor" formula for the multiplication constant are explained and applied to the British experimental reactor. The description of the Raleigh water boiler and its controls leads to a chapter on elementary pile kinetics and the problem of the approach to criticality. The discussion of the effects of radiation on reactor materials is pertinent and not readily available elsewhere, but the following chapter on heat transfer might better be omitted, as not nuclear, and an aspect of engineering lore that is treated with varying degrees of completeness in many excellent texts. The author then proceeds to the elementary design consideration of two reactors, i.e., a gas-cooled enriched reactor and a liquid metal-cooled natural uranium reactor. This is an illuminating exercise illustrating the interaction of the neutron physics, the heat transfer, and the materials restriction on any particular pile design and the sort of compromises the designer must make. The hazards of radiation in terms of its biological effects, the types of radiation arising from the reactor operation, the principles of shielding for protection from the various types of radiations, and finally the problem of disposal of radioactive wastes follow in logical order. The remaining chapters represent a bit of potpourri: that on detection and control instruments is an over-all look at these vital reactor elements; the chapter on neutron experiments in my opinion belongs, if anywhere, in the introductory physics; the chapter on uses of isotopes barely touches on this topic, which may well in the long run be much more important economically and ecologically than the nuclear power application to propulsion or electrical production that comprise the final two chapters.

The book is clearly written and the style is concise, which is fortunate in view of the number of topics covered. Many interesting and illustrative problems follow each chapter and I would not doubt that in substance many of them will reappear in other books on this subject. As is usual nowadays, the format is good. As an over-all survey of the field, it should be quite interesting to an engineer wondering what sort of topics are in nuclear engineering.

However, it has long been my opinion that engineering as a full-fledged profession should be studied at a graduate level rather than at a junior undergraduate level, and that for this reason a more intensive text would be more appropriate. We should assume that if an engineer wishes to enter the nuclear field he would first take a real course in atomic and elementary nuclear physics. The introductory chapters on physics, as well as those on heat transfer, and some of the discussion on thermal stress and creep could well be omitted on the assumption that they would of necessity be treated more completely in any adequate engineering curricula.

With this reservation, however, I can recommend the book as a good first attempt in this field. It may well be that until the reactor technology is further declassified that a more definitive text cannot be written.

Millimicrosecond Pulse Techniques

By IAN D. LEWIS and FRANK H. WELLS (McGraw-Hill Book Co., Inc., New York, 1954, xiv + 310 pages, $7.50). Reviewed by W. A. HIGINBOTHAM, Electronics Division, Brookhaven National Laboratory, Upton, New York.

This volume concerns circuits and techniques recently developed for the study of nuclear processes occurring in the range 10^{-6} to 10^{-9} sec. For the physicist it is an excellent summary of the present state of the art, but it should have a wider audience. Such high-speed techniques are also of interest in computing, radar, television and any field which may use high-speed trigger circuits, wide-band amplifiers and the instruments for fast pulse measurement.

Ionization, proportional and G-M radiation detectors produce pulses with rise times of 0.1 μsec or longer. Scintillation and Cerenkov detectors, developed since the war, give pulses with rise times as short as 0.001 μsec, so that 10^{-10}-sec nuclear lifetimes have been measured. The circuits for use with these detectors have developed rapidly and chaotically in the last eight years. This is the first effort to collect and compile the information from widely scattered sources. The information is evaluated by experts and presented with sufficient mathematical theory and specific technical detail to give a balanced perspective.

The first chapter is a theoretical introduction comparing frequency and transient analyses and presenting a condensed treatment of Laplace transforms. The second chapter treats continuous and lumped constant transmission lines which are basic to the field because of their wide-band response. Other chapters discuss transformers, pulse generators, amplifiers and oscilloscopes. The last two chapters, *Applications to Nuclear Physics* and *Miscellaneous Applications*, are included primarily for the edification of the nonphysicist.

The book is well written and carefully organized. A great many references are given in the text and each is summarized.

One should not expect to be able to build a pulse generator or a coincidence circuit on the information in this book alone. But it will give a good understanding of the nature of the problem and the methods of achieving a solution. The volume will be extremely useful to the newcomer. Millimicrosecond experts may find few new gadgets, but they will find it stimulating, refreshing and a very handy book to have around. A few good

circuits are missing, and the treatment is necessarily somewhat limited. But these shortcomings are not serious, and the book is remarkably up to date.

BOOKS RECEIVED

Permissible Dose from External Sources of Ionizing Radiation (National Bureau of Standards Handbook 59), 79 pages, $0.30. *Government Printing Office, Washington 25, D. C. (To be reviewed.)*

Thermodynamics, by Franklin P. Durham, Prentice-Hall, Inc., 1954, New York, vii + 312 pages, $7.35. This textbook for the engineering student has been written by the author with the belief that most texts on the subject are inadequate from the viewpoint of the student. The basic theory is developed in the first 6 chapters with a minimum of equations, stressing their over-all relationship; following chapters give specific applications.

Medicina Nucleare, by Aldo Perussia *et al.*, Il Pensiero Scientifico Editore, Rome, 1954, xii + 877 pages. This book is an introduction in Italian to medical-biological applications of nuclear physics.

Process Control, by A. J. Young, Instruments Publishing Co., Pittsburgh, 1954, xi + 129 pages, $2.00. Based mainly on articles appearing in "The Industrial Chemist," this book explains the operation of closed-loop control systems, using the frequency-response approach. Written for the plant engineer, it emphasizes practical applications and covers commercially available controllers.

Superfluids, Vol. 2, by Fritz London, John Wiley and Sons, Inc., New York, 1954, xiv + 217 pages, $8.00. Volume 2, "Macroscopic Theory of Superfluid Helium," presents the author's interpretation of liquid helium II as a quantum mechanism on a macroscopic scale rather than as a purely phenomenological theory.

Optics (Lectures on Theoretical Physics, Vol. 4), by Arnold Sommerfeld, Academic Press, Inc., New York, 1954, xii + 383 pages, $6.80. Using Maxwell's equations as developed in Vol. 3 of this series, "Electrodynamics," this volume contains the chapters: *Reflection and Refraction of Light; Optics of Moving Media and Sources; Theory of Dispersion; Crystal Optics; Theory of Diffraction;* and *Addenda, Chiefly to the Theory of Diffraction.*

Fundamentals of Electromagnetic Waves, by Paul C. Shedd, Prentice-Hall, New York, 1954, xi + 191 pages, $5.65. This book, for students of electrical engineering and physics, provides a basis for the study of electromagnetic waves.

ALSO OF NOTE

Table of Sine and Cosine Integrals for Arguments from 10 to 100 (National Bureau of Standards Applied Mathematics Series 32). This hard-cover publication is a reissue of Table 13. *Government Printing Office, Washington 25, D. C., $2.25.*

Protection Against Radiations from Radium, Cobalt-60, and Cesium-137 (National Bureau of Standards Handbook 54). Prepared by the National Committee on Radiation Protection, this handbook presents a revision of the code originally published in Handbook 23. Increased applications of radium sources, change in the maximum permissible dose, and higher-energy, reactor-produced gamma emitters made this restatement of basic principles and attenuation data necessary. The material is applicable to medical and industrial uses. *Government Printing Office, Washington 25, D. C., $0.25.*

Introduction to the Theory of Neutron Diffusion, Vol. 1. This 174-page monograph, by K. M. Case, F. de Hoffmann, and G. Plazek, is sponsored by the Los Alamos Scientific Laboratory as a research aid and for teaching on the graduate level. It gives a detailed discussion of the general equations of one-velocity neutron diffusion theory and of their solution for the special case of a homogeneous infinite medium with isotropic scattering. *Superintendent of Documents, Washington 25, D. C., $1.25.*

A Bibliography of Atomic Power and Related Atomic Energy Topics for the Non-Specialist. This compilation is intended to assist people not in atomic energy programs who wish to know more about atomic power and related topics. References that would interest mainly people with some technical training are indicated. *Public Relations Office, Atomic Energy of Canada Ltd., Chalk River, Ontario.*

Nuclear Notes for Industry No. 3. Selected AEC unclassified reports of interest to industry are listed and abstracted. *Industrial Information Branch, U. S. Atomic Energy Commission, Washington 25, D. C.*

Government-Owned Inventions Available for License—Electrical and Electronic Apparatus (Patent Abstract Series, No. 5). Prepared from the Index of Inventions maintained by the Government Patents Board, under the sponsorship of the U. S. Department of Commerce and the Small Business Administration, this book contains 1,915 patent abstracts. Included are measuring instruments, particle accelerators, controls, tubes, computing apparatus, and X-ray apparatus. *Office of Technical Services, U. S. Department of Commerce (Room 6227), Washington 25, D. C., $4.00 (Order No. 111468).*

U. S. Government Research Reports, Vol. 22, No. 4. This monthly publication provides information on federal research projects for private industry. Formerly the "Bibliography of Technical Reports," the "U. S. Government Research Reports" continue the sequence of volume and issue numbers established by the BTR. AEC reports, including nuclear physics and instrumentation, are selected from "Nuclear Science Abstracts" for possible industrial application. *Superintendent of Documents, Washington 25, D. C., $6.00 per year.*

ORINS Eighth Annual Report. This report discusses the activities, financial statement, and personnel of the Oak Ridge Institute for Nuclear Studies for the year ending June 30, 1954. *Oak Ridge Institute of Nuclear Studies, Inc., Oak Ridge, Tenn.*

Formulas for Computing Capacitance and Inductance (NBS Circular 544). This 69-page publication, by Chester Snow, gives formulas for computing capacitance between conductors of various geometries, self- and mutual inductance of various circuits, and electrodynamic forces acting between coils. *Government Printing Office, Washington 25, D. C., $0.40.*

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ABOUT THE INDUSTRY

Industry Sets Up Reactor Materials Group To hasten industrial atomic energy development, Atomic Industrial Forum is setting up committees to focus attention and effort on problem areas. First to be set up is a nuclear reactor materials committee, thus emphasizing the primary role metallurgy and related work play in developing economic nuclear power. M. A. Cordovi, chairman pro tem, expects the committee to survey adequacy of materials research, help disseminate existing and new data, and initiate and sponsor research and development where it's most needed.

Cooperating with the Forum in organizing the committee are Allegheny Ludlum Steel Corp., Aluminum Co. of America, Babcock and Wilcox Co., Climax Molybdenum Co., International Nickel Co., Lukens Steel Co., Nuclear Metals, Inc., Republic Steel Corp., Titanium Metals Corp., and Vanadium Corp. of America.

Yankee Atomic Floats Stock Issue Needing $317,500 to finance engineering studies and preliminary expenses, Yankee Atomic Electric Co. is in the process of issuing 3,175 shares of $100 capital stock. Yankee, incorporated last fall, plans to build a nuclear power plant in the New England area, will need further capital when it starts building.

Consultants Form Applications Firm Seven scientists and engineers active in applying radiation to industrial and research problems have banded together with a former AEC attorney to form Radiation Applications Inc. They're offering a three-pronged consulting service to industry: First, a monthly report on developments in the industrial radiation field; subscriptions of $50 a year include right to ask questions that do not require extensive research. Second, more extensive consulting service on a contract basis. Third, arrangements for use of radiation sources and facilities needed for a client's research and development.

Included in the group are V. L. Parsegian, former director of research for AEC's New York office; W. R. Singleton, senior geneticist, and B. Manowitz, in charge of fission-product utilization, Brookhaven National Laboratory; J. S. Butts, former assistant chief of AEC's biology branch; E. L. Gaden, Jr., and E. J. Henley, Columbia University's chemical engineering department; E. C. Sargent, former Cleveland Area manager for AEC, and M. F. Pofcher, formerly on AEC's legal staff.

Address of the new group is 342 Madison Ave., New York 17, N. Y.

Standard Oil Building $1-Million Radiation Lab Late this spring, Standard Oil Development Co. will receive a single piece of cobalt containing 3,500–4,000 curies of radioactivity, for which it will pay Brookhaven National Laboratory some $17,000. After this source is installed in a new million-dollar laboratory at the Esso Research Center, Linden, N. J., it will be used to find out how radiation can be used to initiate chemical reactions in petroleum processing.

The new laboratory is designed so that small pilot plants can be exposed to the source in a 6 by 9 ft room shielded by 4 ft of concrete. Workers can watch experiments through a 3-ft lead-glass window and handle apparatus with master-slave manipulators. While experiments are being set up, the source will be lowered into a well in the floor.

The new source is the largest single piece of radiocobalt yet produced, but larger sources—like the University of Michigan's 10,000-curie unit—have been made from several combined pieces.

Standard Oil Development is no newcomer to atomic energy. As far back as 1938, it was studying uranium, has worked for AEC on uranium and plutonium separation-plant design and as heavy-water consultants. It's been using radioisotopes for tracer studies, will expand this use in its new lab.

LETTERS

Cenco Makes H/C Meter

DEAR SIR:

In the October, 1954, issue of NUCLEONICS, page 72, the beta-ray H/C meter is credited as a development of Standard Oil of Indiana and Nuclear of Chicago. Initial development work on the instrument was done by Standard Oil Company (Indiana), the design and manufacture of the instrument by Central Scientific Company. Central Scientific Company and Standard Oil Company (Indiana) are continuing in the development of this application of radioisotopes.

—H. M. SULLIVAN
Vice President, Central Scientific Company
Chicago, Illinois

To clarify the record further, Nuclear-Chicago, according to its president J. A. Schoke, did make some contributions, developed and makes the bidirectional balanced source used in the Central Scientific Co. instrument.—Ed.

Hot-Lab Comment

DEAR SIR:

I just received the November, 1954, issue of NUCLEONICS—the Hot Lab special—and I couldn't wait to congratulate you. I haven't read it yet but I did scan through every single page from cover to cover, and so far I have nothing but high praise for your prodigious efforts. You should feel very proud of the final result.

The only way I can describe this issue is *Beautiful!* Every month NUCLEONICS has been getting better and more interesting, but I'm afraid you really have a pace-setter for November. I hope we have set a precedent and that NUCLEONICS will consider publishing the proceedings of the next Hot Lab Information Meeting in the same manner as this last one. As far as I know, NUCLEONICS is the only logical journal for material of this kind, and as far as I am concerned, the net result of your November issue has been more than satisfactory—it has been ideal.

I hope your advertisers and your publisher share the pride I feel in being part of such a splendid issue.

—L. G. STANG, JR.
Brookhaven National Laboratory
Upton, New York

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NEWS

American Locomotive Gets Package Reactor Contract as 18 Firms Submit Bids, 12 under $4-Million

A low bid of $2,096,753 last month won for American Locomotive Co. the lump-sum contract for design, construction and testing of the Army Package Power Reactor (APPR). The Atomic Energy Commission's Chicago Operations Office awarded this first fixed-price contract for reactor construction on December 15 after 18 of 33 firms invited to bid had submitted proposals. Highest bid was $6.9-million; 12 of the proposals were under $4-million.

APPR costs will be shared about equally by AEC and the Department of the Army. It's reported that Oak Ridge National Laboratory, which evolved the conceptual design for APPR, estimated that the plant would cost $3–4-million. Second and third lowest bids were $2,462,355 and $3,037,586, but the companies making them were not revealed.

American Locomotive's bid was chosen as the most favorable to the government on the basis of price, excellence of design, and responsiveness to other terms of the bid invitation (NU, Oct. '54, p. 22). The company is no newcomer to the atomic energy field; total value of its atomic energy products sold in 1953 was $22-million, and it's estimated this figure was duplicated in 1954. Since 1949, Alco has been producing nickel-clad steel pipe, heat exchangers, tube bundles, gaseous-diffusion gas converter subassemblies, evaporators, coolers, condensers and valve bodies for atomic energy installations. Alco has just completed fabricating 84 special towers for use at Oak Ridge.

Alco's bid was based on Stone and Webster being subcontractor for APPR construction. Stone and Webster has served as architect-engineer on several AEC construction projects, has contracted for PWR plant construction at cost plus $1.

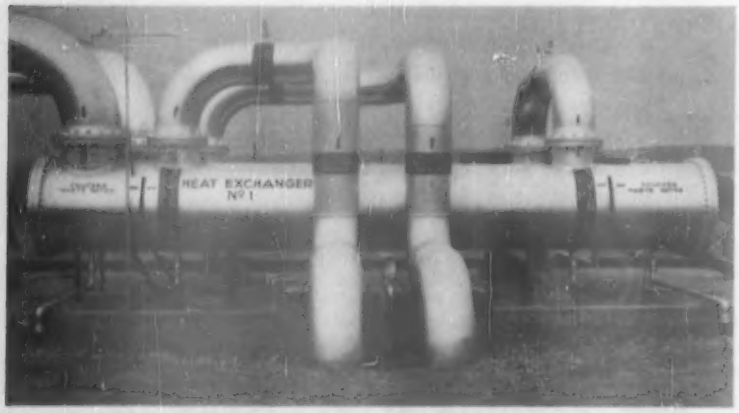
Selection of the Alco bid was made by a board consisting of John Flaherty, manager of AEC's Chicago unit; David Saxe of the same office; Daniel J. Casey, Argonne National Laboratory; Col. J. Lampert, head of the Army-AEC reactor project; and W. K. Davis, deputy director of AEC's reactor development division. Serving on an advisory committee to this board were R. Livingston, ORNL; Milton Klein, ANL; and Earl G. Kunz, of AEC's Chicago office.

With the APPR contract awarded, work is getting underway on the five-phase program spelled out in the specifications sent to prospective bidders. First phase is completion of progress schedule, flow diagram, and heat balance studies. Second phase is preliminary designs of system components, details of plant, site, and safety plans. Third phase is specifications and drawings for fabrication and construction. Fourth phase is fabrication and construction. Final phase before the facility is handed over to AEC-Army is testing (NU, Oct. '54, p. 22).

Current plans call for construction of APPR at Fort Belvoir, Va., site of the Army Corps of Engineers Training Center, with eventual integration of the facility into the Army engineer training program. The prototype reactor plant will be designed so that its components can be transported by air. Electric capacity will be 2,000 kw.

Other companies that made proposals were: American Machine and Foundry; Arrowhead Constructors (joint venture)—Donovan Construction, Winston Bros., C. F. Lytle, Green Construction, and Missouri Valley Constructors; Babcock and Wilcox, and Vitro Corp. of America (joint); Bethlehem Steel; Combustion Engineering; Curtiss-Wright; Ford Instrument; Foster Wheeler; General Electric; Glenn L. Martin; Kidde Industries; Kuljian Corp.; LeTourneau Westinghouse, and Fluor Corp. (joint); Merritt-Chapman and Scott; North American Aviation; Raymond Concrete Pile Co.; and Stearns-Roger Manufacturing Co.

Although they received bid invitations, the following companies did not enter the competitive bidding: Allis-Chalmers; W. F. and J. Barnes; Bendix; U. S. Steel (Consolidated Western Steel Div.); Fairbanks-Morse; Kaiser Engineers; A. D. Little; AVCO Manufacturing (Lycoming Division); Newport News Shipbuilding and Drydock; Ralph M. Parsons; Sverdrup and Parcel, Food Machinery and Chemical (joint); M. H. Treadwell; and Westinghouse Electric.



HEAT EXCHANGERS outdoors at Hanford are integral part of first large-scale application of atomic energy to space heating in the U. S. River water used to cool reactors heats up secondary heat-transfer fluid in these units. Secondary fluid uses 60,000 gallons of ethylene glycol to prevent freezing during shutdowns, carries heat to air conditioning units in several plant buildings. Reactor coolant cannot be used directly because of induced activity

Establish Private Fund for International Atom

Worldwide development of atomic energy is the aim of a private group—Fund for Peaceful Atomic Development, Inc.—set up last month. With initial financing of $150,000 from the Ford Foundation, the organization hopes to foster exchange of information among nonofficial private groups in various countries, as contrasted with official exchanges contemplated under the U. S. and UN programs now being set up.

The purposes of the fund are: (*a*) to foster and encourage throughout the world the private development and utilization of atomic energy for peaceful purposes; (*b*) to survey and report upon the need for peaceful applications of atomic energy in all parts of the world; (*c*) to provide an international clearing house of unclassified information with respect to the technical, managerial, cultural, legal, financial, industrial, agricultural, medical and educational aspects of the private development and use of atomic energy for peaceful purposes; (*d*) to promote the dissemination throughout the world to the extent consistent with national security of knowledge and understanding relating to the peaceful uses and applications of atomic energy; (*e*) to foster and encourage the training of men and women in the skills required by experiments throughout the world at the private development and utilization of atomic energy for peaceful purposes; (*f*) to provide scholarships and fellowships for worthy and qualified students for study, research and training in the development of the peaceful applications of atomic energy; (*g*) to conduct meetings and conferences anywhere in the world for the purposes of promoting knowledge and understanding of peaceful uses of atomic energy; and (*h*) to promote the organization of like groups dedicated to like purposes in other countries of the world.

In its initial operations, the Fund will arrange for task forces of leading industrialists, scientists and other individuals from foreign countries to visit the United States. These task forces will survey unclassified aspects of the efforts both by private groups and the government in this country.

Officers of the Fund are Walker L. Cisler, president of Detroit Edison,

Guest Editorial by Lewis L. Strauss

Chairman, U. S. Atomic Energy Commission

Because of the significance of the forthcoming international conference on nuclear energy, NUCLEONICS invited Mr. Strauss to present his views on the objectives of the conference.

The action taken by the United Nations General Assembly on December 4 when it formally approved the convening of an international conference on the peaceful uses of atomic energy sprang from a decision which President Eisenhower had taken eight months earlier.

In April of 1954, following his stirring proposal before the United Nations for a world pool of fissionable materials for the benefit of mankind, the President authorized me to declare that it was his intention that such an international conference should be convened. This was another step to translate into action his concept of "atoms for peace." The President was deeply aware of the necessity of bringing together the scientists of many nations to discuss not only basic science and specific peaceful applications of atomic energy, but also means of promoting a wider understanding throughout the world of the immediate and important practical benefits in the field of atomic energy.

Secretary of State Dulles, in his address before the General Assembly on September 23, reaffirmed the desire of this government that such a conference be called. The subject subsequently was discussed by Ambassador Lodge in Committee One, and as a result a resolution was offered to the General Assembly.

On December 4 the General Assembly unanimously approved the resolution for "international cooperation in developing the peaceful uses of atomic energy." The first part of the resolution deals with a proposed international atomic energy agency in line with the President's "atoms for peace" proposal. The second section deals with the projected international conference.

The mechanics of setting up the conference will be developed by a small working committee composed of representatives from Brazil, Canada, France, India, USSR, United Kingdom and the United States. This committee also will be responsible for making recommendations to the Secretary General of the United Nations for a detailed agenda as well as the issuance of invitations to the participating states.

The specific purposes of the conference as set forth in the resolution are: ". . . to explore means of developing the peaceful uses of atomic energy through international cooperation and, in particular, study the development of atomic power and to consider other technical areas—such as biology, medicine, radiation protection; and fundamental science—in which international cooperation might most effectively be accomplished."

Dr. I. I. Rabi, the distinguished Nobel laureate, has been designated by President Eisenhower to be the United States representative on the advisory committee to the Secretary General.

There are a number of highly important objectives which it is hoped will be achieved when the conference takes place, and it is the belief of the Atomic Energy Commission that a substantial contribution can be made by the United States to this conference in all areas of peaceful atomic energy activity. The work of the conference in terms of subject matter will probably be divided into three principal parts. One section would deal with the general problems involved in reactor technology since the solution of these problems is important to the eventual development of atomic power. Another section would deal with the immediate and prospective benefits from the application of atomic energy in medicine, biology, agriculture and industry. A third section would deal with fundamental theory in the sciences as it relates to the specific topics on the agenda.

The very nature of science has always been international, and while of course there have been many international conferences in specific areas, the meeting that we have proposed will be the first of its kind to embrace the entire field of peaceful utilization of atomic energy.

With the renewed search for a peaceful solution to the problems facing the free world in the atomic era, we believe this conference can be of great significance, and we approach it with a very real hope that it will help to establish the beginnings of an enduring cooperation in the field of peaceful atomic energy technology.

Sidelights

Libby gets lab in Washington. The Carnegie Institution of Washington has made it possible for W. F. Libby to continue his tritium and carbon-14 research even while a member of AEC. The institution has appointed him a research associate and made facilities available at its geophysical laboratory.

•

General Motors building isotope lab. To fulfill its desire to use radioisotopes in engineering and research studies, General Motors is building a new laboratory at their Detroit Tech Center. Plans call for one of the largest privately financed laboratories in the country, with safety provisions far beyond the minimum. E. J. Martin and A. Sommerville are directing planning.

•

Britain puts first cobalt teletherapy unit into use. Bristol General Hospital, Bristol, England, is now using the first cobalt teletherapy unit built in the United Kingdom. Designed and built at Cambridge University, the unit weighs 700 lb, cost $36,400.

•

Maryland plans nuclear engineering courses. The University of Maryland is setting up nuclear engineering courses in its chemical engineering department. Dick Duffy, formerly of AEC, is in charge.

•

Cordiner tops AEC in estimates of nuclear power use. By 1976, nuclear plants will make up 50% of all new electrical generating plants, according to Ralph Cordiner, president of General Electric. AEC gave nuclear power about one-third of new capacity in 1976 (NU, May '54, p. 76). Cordiner used his estimate before the National Association of Manufacturers to pump for more long-range industrial planning.

•

Sabrejet almost interferes with plutonium production. When an Air Force fighter plane crashed in the restricted area at Hanford early in December, it narrowly missed a building where plutonium is produced.

•

NYU gives radiological safety course. Fundamentals of radiation safety are being taught in a two-week course starting Jan. 10 at New York University. Cooperating with the University's Institute of Industrial Medicine is the College of Engineering and AEC. This is the third year the course has been taught.

•

New institution will use radioactivity in medical research. With $1-million in endowments, the New England Institute for Medical Research will concentrate on applying physical-science measurement techniques, including tracers, to biological studies. Work will be done in buildings now under construction at Ridgefield, Conn.

•

Predicts coastal location for South African nuclear power plants. H. J. van Eck, chairman of South Africa's Industrial Development Corp., has two reasons for believing that coastal industrial centers will get his country's first nuclear power. First, transporting coal from the interior is expensive. Second, there is not an adequate water supply in the interior. Van Eck wants an immediate start on a research reactor, with nuclear power plants "considered" within ten years.

•

Cancer research hospital uses iodine most. In one year, Argonne Cancer Research Hospital handled more than 32,157 millicuries of radioisotopes. Top three radioisotopes in quantity were iodine-131, gold-198, and phosphorus-32.

president; William C. Foster, president of Manufacturing Chemists' Assoc., vice president; Oscar M. Ruebhausen, chairman of atomic energy committee of N. Y. Bar Association, secretary; and Joseph M. Dodge, special asst. to the President on foreign economic policy, treasurer. There are 21 directors, including top business men, scientists and labor leaders.

Temporary headquarters of the group are in Detroit. Offices will also be established in New York and Washington.

French Ask Patent Award for Use of Fission Process

The Atomic Energy Commission's patent compensation board has received a request from the Commissariat a l'Energie Atomique, its French counterpart, for a reasonable award for use of a uranium fission process. The claim is based on five patent applications filed by three French scientists in the U. S. Patent Office in 1939.

While no U. S. patents were ever issued, a Swiss patent was granted in 1944 (NU, Oct. '54, p. 64). The Swiss patent includes a discussion of neutron theory and its application to reactors; it also includes a proposed design for a nuclear reactor.

Under the Atomic Energy Law, AEC can revoke patents covering inventions or discoveries applicable to atomic weapons; the law also allows AEC to make "just compensation" for revoked patents.

Theoretically, the law also provides that AEC reply to claims within four months. But the reply doesn't necessarily have to include a definite answer to the claim, and final action may not be taken for years.

The French patent applications in 1939 were made by J. F. Joliot, H. von Halban, and L. Kowarski. They have assigned their interests to CEA.

In a somewhat parallel case Enrico Fermi and six other Italian scientists were awarded $300,000 for work on transmutation in Rome before 1934 (NU, Sept. '53, p. 76). They had sought $10-million in a patent infringement suit, but had dropped the suit before the award. Just last month, Fermi was awarded $25,000 under a new patent section of the Atomic Energy Act of 1954 for "meritorious contributions."

UN Brings in Randers to Steer International Conference, Advisory Committee Report Expected this Month

Expectations that the international atomic energy conference called for in the resolution unanimously approved by the United Nations General Assembly on Dec. 4, would be on a high technical level were fortified by two events last month. UN Secretary General Dag Hammarskjold figured in both.

First, Hammarskjold announced that Gunnar Randers would serve as his special consultant in setting up the conference. Randers is executive director of the European Atomic Energy society and also is director of the joint Dutch-Norwegian atomic research program.

Second, in sending out formal invitations to seven countries to appoint one representative and possibly an alternative to serve on the conference advisory committee (NU, Dec. '54, p. 5, 70), Hammarskjold spelled out his hope that the appointees would be specialists of a high level in the atomic energy field. Said Hammarskjold later, "As I see it, [this committee] will not in the first place be a committee of politicians, administrators or diplomats, but it will be a committee representing the scientific experts in this field."

Backing up these indications of a high-level technical conference was Hammarskjold's summary of what General Assembly debates indicated as its purpose—that its primary practical task would be to consider economic aspects of atomic power, power-reactor design and operation, and the technology of nuclear engineering on a factual basis. Omitted are isotope applications; whether or not they should be included bears on how much the conference should cover. And the answer to that will come from the advisory committee.

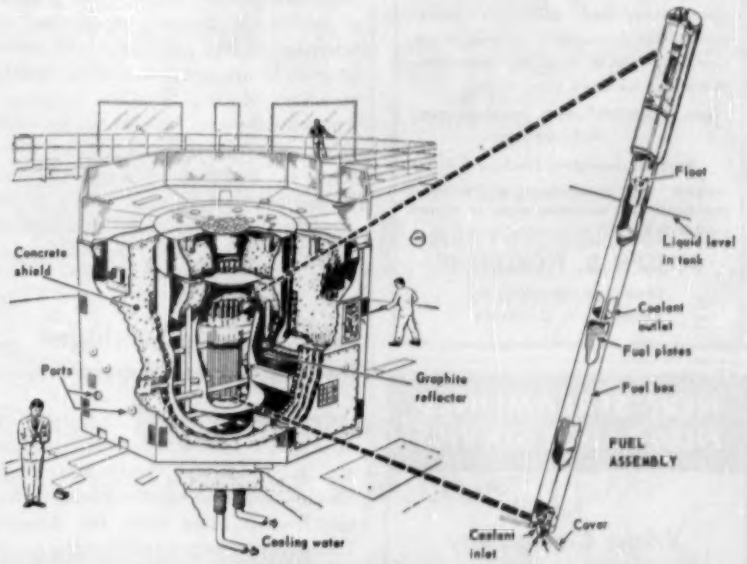
With a target of August for holding the conference, UN officials hope that the advisory committee will have made its final recommendations by the end of this month. Then the Secretariat can start on the actual details of arranging the conference.

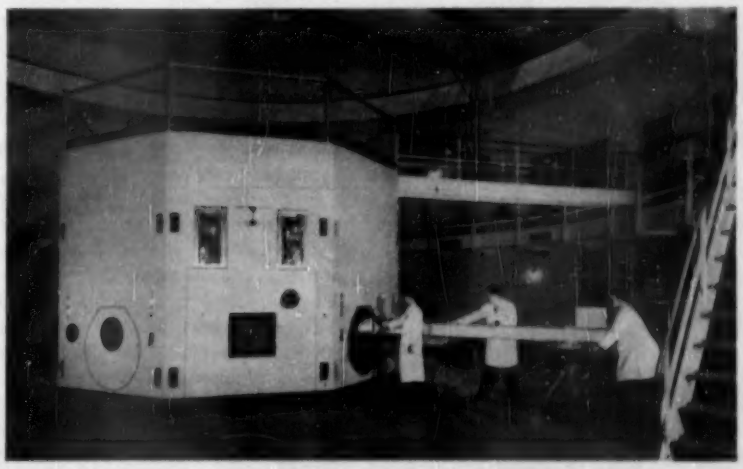
Randers will work directly with Hammarskjold in guiding Secretariat planning and work at the outset. His long-range role has not yet been spelled out. It's not expected that he will devote full time to the project; he still retains his other positions and responsibilities. But it's probable that he will play an important role at the actual conference as the UN leader.

With Randers joining the UN effort, the Secretariat committee headed by Ralph Bunche has been dissolved. Originally, this committee was set up to study means of integrating the international agency and conference into the UN structure. At one point, it was thought that it would continue as the operating group for the conference.

Isotope Course First Step in International Program

Putting the plans it announced before the United Nations for implementing international cooperation in atomic energy into operation (NU, Dec. '54, p. 70), the United States is scheduling a special course in radio-





CP-5 REACTOR at Argonne National Laboratory has been declared an open facility by AEC. Reactor, building, and associated laboratories cost about $2¼-million. Reactor, enclosed in octagonal concrete shield 20 ft wide, provides over 50 experimental openings (NU, Jan. '54, p. 12). Technicians in picture are replacing shield plug with apparatus for neutron-beam experiment; diagram shows reactor construction

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isotope techniques for scientists and engineers from outside the U. S. The course, in content the same as has been taught to over 2,000 students since 1948, will start May 2 at Oak Ridge Institute for Nuclear Studies. Four weeks will be devoted to basic fundamentals and actual techniques of radioisotope use.

After this first course, several foreign applicants will be accepted for each session of the regular course. Registration for the regular sessions is restricted to 32 enrollees; this limitation will also apply to the special session.

Scientists and technicians from the 53 countries receiving shipments of U. S. isotopes are eligible if they have a bachelor's degree, experience or training in the field in which they propose to use isotopes, and an understanding of the English language. Application forms must be on file with the U. S. State Department by February 1. Forms are available at U. S. embassies and legations abroad, or directly from Oak Ridge Institute of Nuclear Studies, Box 117, Oak Ridge, Tenn.

AEC Approves Michigan Reactor Safety Provisions

Construction on the University of Michigan's 1,000-kw research reactor will get underway early this year. Final approval of safety provisions for the facility came from the Atomic Energy Commission last month.

It is reported that, because this reactor is designed to run at a higher power level than any other non-AEC reactor and will be located on a university campus, it took a number of revisions of plans before the AEC reactor safeguards committee would give its approval. As a special precaution, the reactor building is a 40-ft-high by 70-ft-square box with one-foot concrete walls designed to contain radioactive material in case of an accident.

The two-foot-square reactor core will be suspended under 20 feet of water in a 40,000-gallon tank. Fuel will be contained in 20 aluminum cans, each containing 18 aluminum-uranium alloy strips.

Preliminary AEC approval and a guarantee of uranium fuel supply was given last June, subject to approval of safety provisions.

When the facility is completed in 1956, it will originally be operated at an average power of 100 kw. A grant of $1-million from the Ford Foundation is financing reactor construction. Babcock and Wilcox Co. designed the reactor, which is based on the swimming-pool concept originated at Oak Ridge National Laboratory. Smith, Hinchman and Grylls, Detroit architectural and engineering firm, designed the reactor housing.

Will Discuss High-Energy Physics at Rochester

The fifth annual Rochester conference on high-energy nuclear physics will be held at the University of Rochester January 31 through February 2 this year. With total registration limited to 100, foreign representation is expected to be unusually large—R. E. Marshak, conference chairman, predicts that 30 scientists from at least 12 countries will attend.

A complete record of conference proceedings will be made available to high-energy physics laboratories. Subjects scheduled for discussion include nucleon scattering at high energies, including polarization effects; meson physics, including field theory; and elementary particles.

"Use of Sealed Sources" Scheduled at ORINS

A two-week, two-part course in industrial uses of sealed radioactive sources will be taught at Oak Ridge Institute of Nuclear Studies, April 18 to 29. Participants can enroll for either or both weeks.

The first week will be devoted to safe handling of sealed sources. Lectures and laboratory experiments will familiarize enrollees with various sealed sources, problems in handling them, and methods in personnel safety as well as providing basic principles for background. This part of the new course is designed for personnel in a position to direct or teach others how to use radioactive sources.

The second week, aimed at supervisory personnel, will consider industrial applications of sealed sources. Typical techniques for radiography, gaging and instrumentation will be discussed and demonstrated. Problems brought up by participants will be considered.

Further information can be obtained from R. T. Overman, chairman, Special Training Division, ORINS, Box 117, Oak Ridge, Tennessee.

RAW MATERIALS

UNITED STATES: discover more ore south of Moab, Utah; Vitro Uranium Co. enters mining. Lisbon Valley Uranium Co. has discovered ore at a depth of 800 ft in two deposits 9 miles southeast of the Steen Mi Vida mine. U_3O_8 content is about 0.3%. Continental Uranium, Inc., already has blocked out 70,000-ton reserves at an intermediate site along this same fault, which extends from the Steen property.

Vitro Uranium Co., until recently engaged only in milling of uranium ores, has started exploration and drilling as the first step in expanding its operations to include mining of uranium.

PERU: signs ore contract with U. S. AEC. Details of an agreement providing for sale of Peruvian uranium ores and concentrates to the U. S. have not been announced, but Peru has set up a payment scale for industry. Government will pay $7.70/kg for U_3O_8, with a $2.75/kg premium for U_3O_8 from ore of more than 0.5% content. Government charge for processing will be $15/dry ton.

FRANCE: 20-ton minimum for ore sale. Commissariat a l'Energie Atomique is buying uranium extracts produced by companies in Britanny, Normandy, and the Massif Central provinces, but only in lots of 20 tons or more. Price scale, guaranteed for five years, is 4,000 francs/kg of U_3O_8 if it is present in concentrations greater than 0.2%. Ore better than 0.4% gets a premium of 1,000 francs/kg.

SOUTH AFRICA: discloses exports of "prescribed materials." Foreign trade statistics issued by the Standard Bank of South Africa for the first three quarters of 1954 include for the first time export of "prescribed materials under the atomic energy act"—uranium ores and concentrates. Value of exports quadrupled over same period in 1953; value quoted for 1954 was 2.3-million South African pounds. Other sources predict that income from South African uranium will exceed gold's.

ISRAEL: expanding low-grade ore processing from pilot-plant stage. With large deposits of low-grade phosphate ores, Israel has developed a new uranium extraction process with costs comparable to those achieved in processing higher-grade ores. Uranium metal has been produced on a pilot-plant basis; now production is being expanded to an industrial scale.

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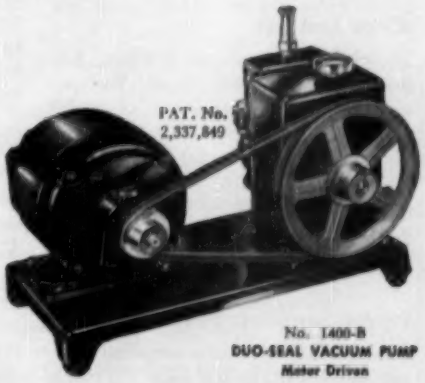

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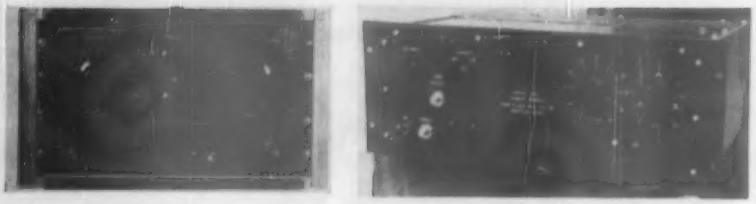
PRODUCTS AND MATERIALS



Regulated High-Voltage Supplies

These two power supplies for nuclear instruments have either negative or positive output.

Model BL-R1 supplies 0–10 ma at 500–2,600 v, with ripple and noise below 5 mv. Calibrated panel controls (above, left) adjust and indicate output voltage, allowing 1% resettability. Regulation is 0.05% for line variations from 100–130 v, and full load variation. Long-time stability is 0.5%. Unit is available for panel mounting or cabinet housed. *Clegg Laboratories, 142 S. Livingston Ave., Livingston, N. J.* (P-1)

Voltage controls accurate to 2%, regulation of 0.03% for 20% line-voltage change or full-load change, are features of model 402 power supply (above, right). Output is 1 ma at 500–1600 v. Noise and ripple are 20 mv; short-term stability is 0.01%, long-term 0.1%. *John Fluke Mfg. Co., Inc., 1111 W. Nickerson St., Seattle 99, Wash.* (P-2)

ELECTRONIC INSTRUMENTS AND APPARATUS

45-kv Test Set

Model 437 (above) has 0–45-kv, 2.5-ma output with 5% ripple. Voltage-doubler circuit, consisting of metal rectifiers, high-voltage transformer, filter capacitors, and meter multipliers, is oil-immersed. Caster mounted, the unit measures 24 × 24 × 36 in., weighs 250 lb. *Associated Research, Inc., 3758 W. Belmont Ave., Chicago, Ill.* (P-3)

Power Supplies: 0–100 v

Model MA65 magnetic-amplifier supply delivers up to 5 a with 1% ripple and regulation. Also available are models MA640 (4.5–7.7 v, 0–40 a) and MA2850 (23–32 v, 0–50 a, 3-phase operation). *Sorensen, 375 Fairfield Ave., Stamford, Conn.* (P-4)

Model 1020 F provides up to 20 a with 5% ripple, built-in meters. *Rapid Electric Co., 2881 Middletown Road, Bronx 61, New York.* (P-5)

A new line of 25–29-v magnetic-amplifier power supplies with capacities to 1,000 a have 2% ripple, 0.2-sec recovery time. *McColpin Christie Corp., 3410 W. 67 St., L. A. 43, Cal.* (P-6)

Model MR2432 is a tubeless magnetic-amplifier-regulated power supply rated at 24–32 v and 200 a. Also available are 0–32-v, 25-a; 24–30-v, 100-a; and 5–32-v, 15-a models. *Perkin Engineering Corp., 345 Kansas St., El Segundo, Cal.* (P-7)

Model 2600 has continuously variable 0–50-v, 2-a output. Ripple is below 1 mv; regulation is within 5 mv for 20-v change in input. *Kepco Laboratories, 131–38 Sanford Ave., Flushing, N. Y.* (P-8)

Power Supplies: Above 100 v

Model PS110 offers 7 full-scale constant-current ranges from ± 50 μa to ± 50 ma at a maximum load voltage of 100 v. It also provides three regulated voltage ranges from ± 200 v to ± 10 v at 50 ma. *Teletronics Lab., Inc., 54 Kinkel St., Westbury, New York.* (P-9)

Model MR-250 has 200–300-v, 2-a output with 0.2% ripple and 0.2% regulation. Other models have outputs from 4–8 v, 20 a to 80–120 v, 6 a. *Magnetic Research Corp., 200 Center St., El Segundo, Cal.* (P-10)

Model 3-150-L power supply has dual ± 0–300-v and 6.3-v a-c heater-voltage outputs that can be ganged. *Dressen-Barnes Corp., 250 N. Vinedo Ave., Pasadena 8, Cal.* (P-11)

Model 701 is an unregulated 0–250-v, 90-ma supply with 20-mv ripple that also provides 6.3-v, 3-a heater power. Model 702 is regulated supply having three outputs: 0–400 v, 200 ma; 0–150 v negative; 6.3 v, 8 a. *Shasta Division, Beckman Instruments, Inc., P. O. Box 296, Station A, Richmond, Cal.* (P-12)

Light, compact model 71 has 0–500-v, 200-ma line-and-load regulated, and 0-200, 9 ma negative outputs as well as dual 6.5-v, 5-a filament supplies. *Lambda Electronics Corp., 103–02 Northern Blvd., Corona 68, New York.* (P-13)

Model 219 A has 0–600-v, 1-a; 0–150-v, 5-ma, and 6.3-v, 10a outputs plus vernier control for precise voltage adjustment. Several other models are available. *Electronic Measurements Co., Inc., Eatontown, N. J.* (P-14)

Model 2004A voltage supply is line-regulated to 0.01%, has six fixed voltages from 10 to 500 v and a 5–500-v variable range. *Keithley Instruments, 3868 Carnegie, Cleveland, O.* (P-15)

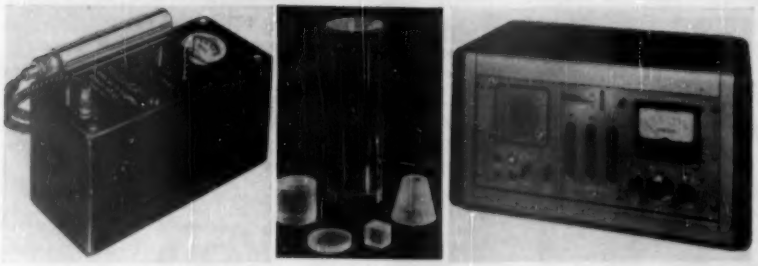
Model 1 power supply is rated at ± 200–325 v, 100 ma with 1% regulation; 6.3-v, 3-a filament power is also provided. *Associated Specialties Co., 1751 Main St., Orefield, Penn.* (P-16)

Model 712B has four heavy-duty outputs: 0–500-v, 200-ma, regulated; fixed 300-v, regulated; 0–150-v for bias; 6.3-v, 10-a for heater power. *Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Cal.* (P-17)

Sensitive multimeter. Polyranger model C offers 14 scales from 1 ma to 10 a and from 1 v to 1,000 v. Mirrored scale length of 6.3 in. matches ¼% accuracy. *Sensitive Research Instrument Corp., 9 Elm Ave., Mt. Vernon, New York.* (P-18)

Regulation meter. Model D-1 measures power-supply internal resistances from 0.02 to 1,000 ohms in 0–500-v power supplies. Can also measure a-c voltage, ripple, and noise. *Alto Scientific Co., 3404 Cowper St., Palo Alto, Cal.* (P-19)

RADIATION DETECTORS AND ACCESSORIES



New Radiation Detection Equipment

A meter for α- β- or γ-rays, a plastic scintillation phosphor, and a scaler with interchangeable decimal and binary output have been announced.

SU-14 (above, left) has two G-M probes, one with side window and sliding shield for selective monitoring of medium-energy β- or γ-rays, other with thin end window for low-energy β- or α-particles. Meter has two sets of ranges —0.25–25 mr/hr and 500–50,000 cpm, in multiples of 10. Time constant is automatically changed with scale range. Battery pack has 150 hr continuous life. Sensitivity drift is 0.05%/hr. *Tracerlab Inc., 130 High St., Boston 10, Mass.* (P-20)

Plastic scintillator, Pamelon, easy to cut and polish, is available in bulk or specially machined sections. Phosphor (above, center) emits at 4,600 Å has decay constant of 0.8×10^{-9} sec, specific gravity of 1.05, melting point of 110° C, radiation absorption 2.5%/in. Beta light yield relative to anthracene is 0.5. Pamelon is addition to line of bulk and prepared scintillators, including NaI, ZnS, CdS. *Isotope Developments Ltd., Finsbury Pavement House, 120 Moorgate, London E. C. 2, England.* (P-21)

Newly announced, the model 200 scaler shown in photo (above, right) with interchangeable binary and decimal units has mercury-pulse generator and 5651 reference tube. Shielded high-voltage supply is patterned after Higginbotham circuit. Scaler can be used as integral type pulse-height analyzer using 0–87.5-v discriminator. *Radiation Instrument Development Lab., 2337 W. 67 St., Chicago 36, Ill.* (P-22)

Miniature Decade Counter

Four types of miniature electronic decade counters that measure $1\frac{1}{4} \times 3\frac{1}{4} \times 3\frac{3}{4}$ in. exclusive of tubes have been announced. The scalers are 20, 40 and 100 kc, plus a 10-cps output stage that can feed a mechanical counter. All counters use the EIT decade scaler tube. The 40 and 100 kc types can be furnished with input shaper, in which case two miniature tubes rather than one are used along with the EIT tube. *Ransom Research, P. O. Box 382, San Pedro, Calif.* (P-23)

Ionization-Type Monitor

Model 2582 battery-operated ionization-type survey meter, for low-level surface measurements, detects alphas down to 1 Mev and betas down to 15 kev; three alpha ranges cover 0–12,500 cpm. The 40-in³ ion chamber has 0.5-mg/cm² rubber hydrochloride window. *Nuclear Instrument and Chemical Corp., 229 W. Erie St., Chicago 10, Ill.* (P-24)

Milli-μsec Pulse Generator

Model PG-215 has mercury relay plus delay-line pulse-shaper to give pulses with rise and decay times down to 1.2 mμsec at 60 or 120/sec rate. Model PGA-220 accessory unit contains standard coaxial cable to give 25 sets of rise and decay time. *Telectronics Laboratory, Inc., Westbury, N. Y.* (P-25)

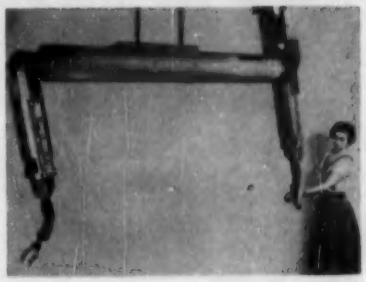
Pulse amplifier. Maximum output of 150 v with gain of 40 db is attained with overshoot and compression less than 5% by this model 120 video amplifier. *American Electronics Labs., Inc., 641 Arch St., Phila. 6, Pa.* (P-26)

Counter chronograph. Model 800 has 10-mc crystal oscillator and decade counters to measure time intervals to 100,000 sec. in 0.1-μsec steps. Gating to 0.1 μsec means time intervals as long as $\frac{1}{10}$ sec can be measured to 1 ppm or better. *EPIC, 42-10 27 St., Long Island City 1, N. Y.* (P-27)

Interval generator. Model 3157 has 1-mc crystal oscillator and decade counters to provide time intervals with preset integral number of microseconds from 0–999. *Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.* (P-28)

Pulse generators. Two models put out half-sine-wave pulses at rates of 15–750,000 cps and 0.2–4.5 mc. Third, model 1003C, gives 0.1-μsec, 0–35-v pulses at triggered rates to 10 kc. *Burroughs Corp., Electronic Inst. Div., 1209 Vine St., Phila. 4, Pa.* (P-29)

RADIOACTIVITY MATERIALS AND APPARATUS



Remote Manipulators

G. E. MAN master-slave manipulator (above), developed in conjunction with Knolls Atomic Power Lab, is through-wall type. Forearm azimuthal motion is ±180 deg; wrist twist is ±90 deg; wrist elevation, ±55 deg. Transmission system employs tape, cable and Nylon pulleys. Parallel operation of master and slave is normal, but 15-deg toe-in to 60-deg toe-out is available. A heavy-duty remote joystick-con-

Products Index

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trolled electrical manipulator with three arm and wrist motions as well as a 40-lb grasp is also available. *Alderson Research Laboratories, 10 East 88 St., N. Y., N. Y.* (P-30)

Thickness Gage

Ekco N504 beta-ray gage uses Tl^{204} or Sr^{90} source to measure from 1 to 550 mg/cm² with 1% accuracy. Either balanced measurement against a standard or direct measurement is available. Response time varies from 0.25 to 60 sec, can be shortened at expense of accuracy. *American Tradair Corp., 405 Lexington Ave., N. Y. C.* (P-31)

Thickness Control

Radioactive gage and control holds 14-mil thickness within ±0.2 mils on plastic foil fed at 13 ft/min. Three heads monitor edges and center of sheets up to 5.3 ft wide, servo system controls calenders at 20-sec intervals or less. *Landis and Gyr S. A., Zug, Switzerland.* (P-32)

TV Camera and Monitor

Model 3AX is economical, completely self-contained television camera with output in channels 2–6 for use with commercial receivers as well as 72-ohm video output. KM 201A monitor also available. *Kirk-Michaels Labs., 550 Beverly Rd., Teaneck, N. J.* (P-33)

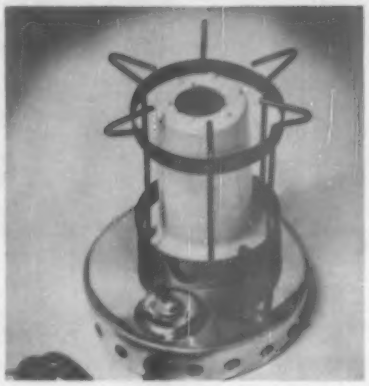
C^{14}-labeled compounds. Uniformly-labeled, 99.5% pure, 1μc/mg glucose, fructose, sucrose and starch are available in crystalline powdered form. *Tracerlab, Inc., 130 High St., Boston 10, Mass.* (P-34)

Isotope cart and arm. Sturdy cart easily supports scalers on two 20 × 36 in. shelves. Gear-driven elevator holds maneuverable arm that supports scintillator-collimator (not supplied). *Isotopes Accessories Co., 5648 Cedar Ave., Philadelphia 43, Pa.* (P-35)

Gas filter. Economical filter removes solid or liquid particles from 110 in³/min gas stream with only 2-in.-water pressure drop. Filter is bidirectional, can operate at 300° F; efficiency is unaffected by accumulated filter residue. Models to 1,200° F are available. *Charles Engelhard, Inc., 850 Passaic Ave., East Newark, N. J.* (P-36)

Aerosol sampler. Automatic 100% collection of dusts, smokes, etc., sampling rates to 50 cm³/min, and permanent record are offered. *Joseph B. Ficklen, 1848 E. Mountain St., Pasadena 7, Cal.* (P-37)

LABORATORY INSTRUMENTS AND APPARATUS



Heating Devices

Two new heating devices have been announced.

Horo Electro-Bunsen-Burner (above) is a 500-w electric heater that directs hot air (up to 850° C continuous) on objects placed on knobs on top of porcelain chimney. Chimney interior of heat-and acid-resistant alloy acts as radiator. Operation is claimed to be clean and odorless, with even heat. Test-tube contents boil in 30–40 sec, it is stated. Heater uses 110 or 220 volts, a-c. *Modern Laboratory Equipment Co., 1809–11 1st Ave., New York City 28, New York.* (P-38)

Inorganic-film-type heating element has operational temperatures to 500° F, power densities to 40 w/in.². Because of nonorganic structure, element is stable and unaffected by hydrocarbons and most acids. It is claimed to have excellent abrasion and corrosion resistance. *ThermoLab Corp., 11430 Hart St., N. Hollywood, Calif.* (P-39)

Porous Teflon Filters

Porous Teflon with a mean-pore-size of 9 microns is being produced in disks of up to 12 in. d., with solid Teflon rim for integral gasketed mounting. Filter is stated to remove all particles larger than 3 microns from liquids and 1 micron from gases. Flow capacity is 45 gal/min/ft² at 5 psi differential for organic liquids of 1 cp viscosity. Filter can be used with all commercial acids, caustics or organic solvents. *Porous Plastic Filter Co., Glen Cove, N. Y.* (P-40)

Contact Microradiograph

Type CMR5 contact microradiograph unit uses new miniature 1–5-kv X-ray tube with 50-μ-thick beryllium window that passes soft X-rays. With commercial fine-grain film, resolution to 0.5 micron is possible. Focus of X-ray tube is 0.3 mm; tube rotates 180 deg. Useful magnification of 500 × is readily obtainable. *North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.* (P-41)

Melting-Point Apparatus

Kofler testing hot benches have metal body and electrically heated element that provides almost linear temperature drop in range 10–260° C. To determine melting point, substance is put on surface of preheated body. In a few seconds, sharp dividing line between solid and liquid appears. Temperature is read from scale on instrument. Accuracy is 1° C. Known melting point substances calibrate instrument. *Wm. J. Hacker & Co., Inc., 82 Beaver St., N. Y. 5, N. Y.* (P-42)

Mobile Equipment

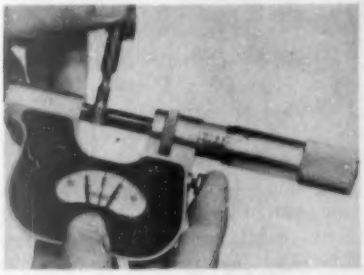
Mobile drying, refrigeration, and vacuum equipment can be obtained.

Self-contained portable laboratory dryer (above) is available for rental, rental-purchase, or purchase. Dryer uses steam- or electrically-heated air, and can be used for tray, pole, roll or plate drying. All controls and charts for manual or automatic operation are mounted on dryer face. *C. G. Sargent's Sons Corp., Graniteville, Mass.* (P-43)

Caster-mounted Lanco cooler has ⅓ hp oil-sealed Freon-12 compressor and air cooled condenser. Cooler can cool 5-gal water bath from 75° F to 32° F in less than 2 hr. Temperature controlled within accuracy of thermoregulator in range 0° F to ambient. Size is 22½ × 14 × 14 in. *Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 29, Ill.* (P-44)

VacForm vacuum pump with 29½ in. Hg ultimate at sea level is mounted

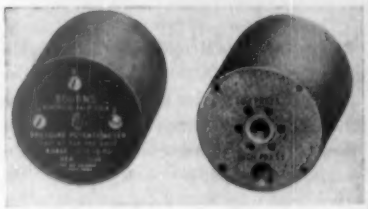
on ball-bearing caster wheels. Pump is 3½ ft high, needs 4 × 2½ ft of floor space. Pump unit has 3-hp motor, includes 50-gal welded surge tank. *Vacuum Forming Corp., 76 Bayles Ave., Port Washington, N. Y.* (P-45)



Indicating Micrometer

Master Compar indicating micrometer (above) is micrometer and comparator in one. Instrument has range of 0–1 in., with 0.0001-in. accuracy. Resetting to zero takes less than 5 sec. Tungsten carbide anvils are standard equipment. Tool detects out-of-roundness, ovalness and taper. Larger sizes, up to 4 in., have removable indicator. *George Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y.* (P-46)

PRESSURE TRANSDUCERS



Four New Types

Several pressure transducers for differing conditions have been announced.

Model 508 differential-pressure potentiometer (above) is 2½ in. diameter × 2⅝ in. long. Standard resistance values are between 1,000–10,000 ohms; unit rating is ½ watt at 160° F. Gage is available in 17 pressure ranges. *Bourns Laboratories, 6135 Magnolia Ave., Riverside, Cal.* (P-47)

Miniature flush-diaphragm strain-gage transducer has the sensing diaphragm located directly in the surface under pressure. Unit is ½-in. in diameter; is available in following pressure ranges: 2.5, 5, 10, 25, 50, 100, and 200 psi. *Electronic Engineering Associates, 1053 Brittan, San Carlos, Cal.* (P-48)

New capacitive-type pickup oper-

3
FIELDS
1
Instrument

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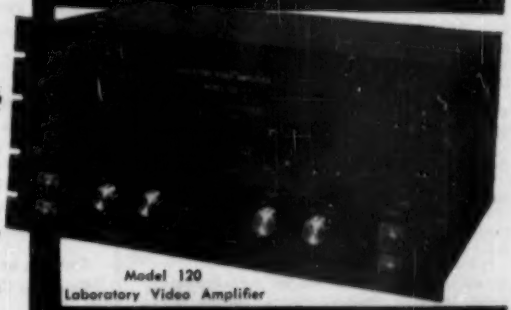

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Laboratory Video Amplifier

Less than 1 CPS to 10 MC/S
Variable Impedance Input
Variable Impedance Output
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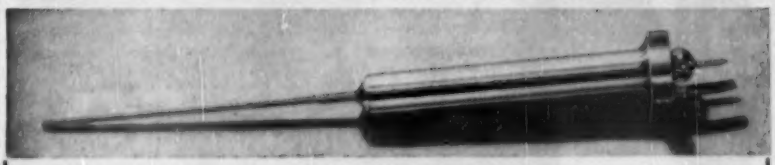

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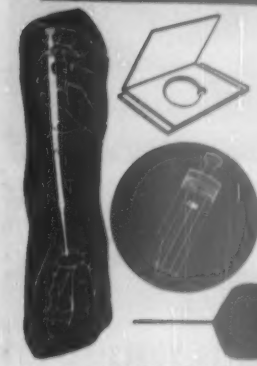

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ates at temperature up to 6,000° F, in corrosive atmospheres. Gage features pressure ranges of 1–75,000 psi; output to 15 v with 25,000 ohm load; frequency response from 0–10,000 cps; flush-diaphragm construction. *Photocon Research Products, 421 N. Foothill Blvd., Pasadena 8, Cal.* (P-49)

Model S-3 reluctance gage is ¾-in. × ¾-in. × 1 1/16-in.; is made of Invar. Gage has pressure ranges from ±1–±100 psi. It can be operated as differential gage. Characteristics: 50-μsec rise time; .1–.4% hysteresis; .03%/g acceleration sensitivity; and .01%/° F zero scale shift with temperature. *Ultradyne Engineering Labs., Inc., P. O. Box 8007, Albuquerque, N. M.* (P-50)

INDUSTRY NOTES

▶**Pioneer Industries, Inc.,** Reno, Nev., will manufacture radiation detection equipment for survey work. Temperature compensating circuit and new scintillators will be used in new scintillation counter.

▶**Kepco Laboratories,** Flushing, N.Y., has added 15,000 ft² to triple its production area for manufacture of voltage regulated power supplies. New engineering development and research lab is part of new plant.

▶**Simpson Electric Co.,** Chicago, Ill., has acquired 100,00 ft² plant to manufacture Greibach bifilar-suspension-type meter movement and other products. Simpson is exclusive licensee for this rugged movement.

▶**Synthetic Mica Corp.,** Caldwell, N. J., subsidiary of **Mycalex Corp. of America** will begin production early in 1955 of worlds first synthetic mica. Eventual manufacturing area can be 150,000 ft².

LITERATURE AVAILABLE

Zirconium facts. New 65-page booklet gives mechanical, physical, and chemical properties of zirconium. Fabrication information is also presented in this worthwhile compilation about a vital reactor material. *Carborundum Metals Co., Inc., Akron, N. Y.* (L-1)

Labeled compounds. Available C^{14}, N^{15}, S^{35}, P^{32}, and I^{131} labeled compounds are listed. *Bio-Rad Labs., 800 Delaware St., Berkeley, Cal.* (L-2)

Nuclear electronics. Scalers, ampli-

fiers, scintillation counters, dosimeters, etc. are described in bulletins about Ekco products. *American Tradair Corp., 406 Lexington Ave., New York 17, N. Y.* (L-3)

Nuclear gages. Bulletin 105 describes density, level, and thickness gages. 10 p. *Ohmart Corp., 2236 Bogen St., Cincinnati, Ohio.* (L-4)

Electrometers. Catalog describes vacuum-tube electrometers and their theory. 12 p. *Keithley Instruments, Cleveland 15, Ohio.* (L-5)

Tube manual. RCA receiving tube manual, RC-17, lists more than 500 tubes, discusses theory and applications. 300 p. *RCA, Harrison, N. J.* (L-6)

Spectroscopic electrodes. New catalog gives data on ultrapure graphite as well as other spectroscopic materials. *United Carbon Products Co., Bay City, Mich.* (L-7)

Spectrograph. Plane-grating spectrograph with order sorter is described in EB-10-54. 12 p. *Jarrel-Ash Co., 26 Farwell St., Newtonville, Mass.* (L-8)

Cold-casting compound. Liquid-polymer rubbers are described in new bulletin. *Thiokol Chemical Corp., 780 N. Clinton Ave., Trenton 7, N. J.* (L-9)

Teflon. Folder describes rod, sheet, tape, tube, and O-ring forms available in Teflon. *Micromold Corp., 11 Centre Pl., Yonkers, N. Y.* (L-10)

Lab aids. Various paints, cements, lubricants, and cleaners valuable in laboratories are described. 8 p. *Varniton Co., 416 N. Varney St., Burbank, Cal.* (L-11)

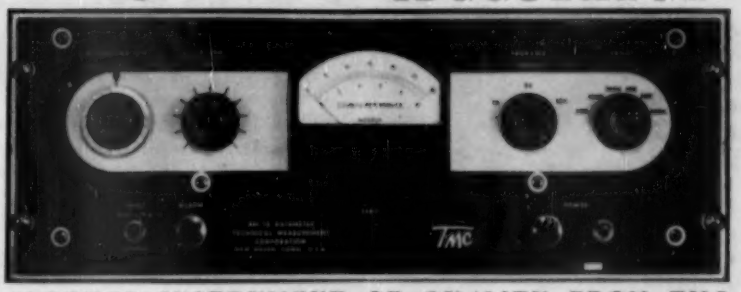
Rubber engineering. Second issue of handbook of standards and techniques in rubber gasketry is off the presses. 82 p. *Minnesota Rubber and Gasket Co., 3630 Woodale Ave., Minneapolis 16, Minn.* (L-12)

Selenium rectifiers. Bulletin SR-1A lists construction, ratings and applications for full line of rectifiers. 8 p. *International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.* (L-13)

Plating solutions. Information available on Rh, Pd, Au, Pt, and Ag plating materials. *Technic, Inc., Providence 1, R. I.* (L-14)

Mass spectrometers. Analytic and leak-detecting instruments are listed. 12 p. *Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 15, Cal.* (L-15)

UNEQUALLED ACCURACY



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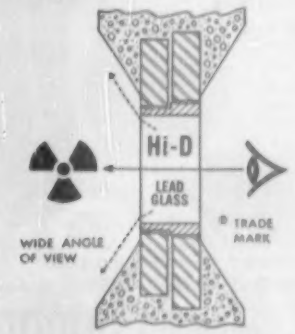

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Printed copies of the letters patent may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents a copy, payable by check or money order. Specify the patent number and title when ordering.

These abstracts have been furnished by the Index of Inventions, maintained by the Government Patents Board, Washington, D. C.

Means for controlling flow of electrolyte to an electrolytic cell* (2,678,300), Julian M. Sturtevant—Apparatus used in separating isotopes by countercurrent flow to cathode. Flowing-liquid average temperature is responsive to changes in countercurrent flow; resistance unit varies with flowing liquid temperature to regulate electrolyte flow and to maintain bath temperature.

Mechanical register* (2,678,773), William E. Glenn, Jr.—Register for counting electrical pulses has low-mass magnetic disk rotor supported on shaft mounted on antifriction bearings; rotor is positioned between pole tips of permanent magnet and electromagnet. Indicator determines angular movement of rotor.

Radiation detector system† (2,679,011), Kenneth N. Fromm—D-C potential source is connected between center conductor and wall of gas-filled counter tube through large resistance. When radiation enters tube, ions are deposited on center conductor to produce charge, which leaks off slowly.

Ion source* (2,679,597), Clarence M. Turner—Pair of metal electrodes are a-c coupled. Grid directs electrons emitted by one electrode into surrounding gaseous medium to ionize it. Temperatures of electrodes relative to each other are controlled. Suitable for separating such metals as Cu, Co, and U.

Polaroscope* (2,680,227), Q. A. Kerns—For electrochemical analysis of electrolytic solutions, visual polarogram is automatically produced during predetermined fraction of interval between birth of mercury drop and breaking off of drop at capillary electrode tip.

Neutron scintillation counter* (2,681,416), B. W. Thompson—Spherical metallic housing opaque to light and charged particles and transparent to neutrons has thin hydrogenous layer on inner housing surface and thin layer of proton-sensitive fluorescent material on inner surface of hydrogenous material, which emits light detected by photomultiplier.

Extraction apparatus* (2,682,452), L. Wainwright—With liquid pumps as only moving parts, two liquids, at least partially immiscible and of different specific gravities, are contacted and separated by countercurrent extraction.

Gamma and X-ray dosimetric method* (2,682,510), G. V. Taplin, C. H. Douglas—Two-phase system comprising aqueous dye solution in contact with low-molecular-weight chlorinated hydrocarbon provides stable, reliable, radiation-sensitive system that indicates exposure by color change.

Contacting device* (2,682,583), F. R. Shonka, R. F. Selman—Sealed moistureproof chamber and magnetic switch eliminate electrical leakage caused by physically separating electrode of ionization chamber from its terminal on outer surface of dosimeter casing.

Ion source* (2,682,611), W. M. Woodward, L. G. Smith—Source produces continuous supply of metallic and metallic-compound ions, e.g., Co, Cu, U, or their halides, for isotope separation. Ionizable material is automatically and intermittently fed onto anode.

Control rod drive mechanism* (2,682,785), B. C. Cerutti, H. V. Lidtenberger—Device permits slow withdrawal of safety rod from active portion of reactor to allow control elements to operate and rapid insertion of rods to prevent a runaway.

Particle and gamma ray energy spectrometer* (2,683,221), B. R. Gossick—Apparatus comprises proportional counter in combination with means for producing collimated neutron beam, solid hydrogenous radiator, and linear pulse amplifier biased to count large pulses.

Radiation meter* (2,683,222), G. Failla, H. H. Rossi—Radiation-permeable container, containing ionizable gas, encloses conducting element. Gas is shielded against radioactive means for changing charge on element.

Shielding window against radioactivity and composition therefor* (2,683,650), W. B. Doe—Stabilization of aqueous concentrated solution of commercial zinc bromide against deterioration and discoloration under intense gamma radiation for long period of time is obtained by adding hydroxylamine hydrochloride up to 0.9*M*.

Separation of americium and curium from aqueous solutions* (2,683,655), D. F. Peppard, P. R. Gray—Aqueous concentrated nitric acid medium is contacted with substantially water-immiscible alkyl phosphate medium; curium values are preferentially held by phosphate and americium by aqueous medium.

Ion beam measuring device* (2,683,814), R. L. Mather—Beam-energy measuring device determines angle of emission of secondary radiation as function of bombarding energy.

Radioactivity measurement* (2,685,027), L. W. Alvarez—To measure rapidly decaying radioactivity, counter and timing pulses ¼ sec apart are amplified and fed into coil; pulses are transferred as magnetic areas on wire passing through magnetic circuit of coil; wire is wound on reel and may be played back.

Process for preparing boron* (2,685,501), J. S. Spevack—Boron halide is reduced by forming fine dispersion of molten alkali metal in gaseous medium and reacting with boron halide at elevated temperature.

Water cooled insulator* (2,686,827), B. H. Roffee—Improved insulator, with depression at one or both ends, is fitted with means to flow cooling medium therethrough.

Isotope separator* (2,686,880), W. E. Glenn, Jr.—Linear-type time-of-flight separator comprises in part ion generator, electric field for accelerating ions, and electrostatic deflection for collecting ions.

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* Administered by Chief, Patents Branch, Atomic Energy Commission, Washington 25, D. C.

† Administered by Patent counsel, Department of the Navy, Washington 25, D. C.

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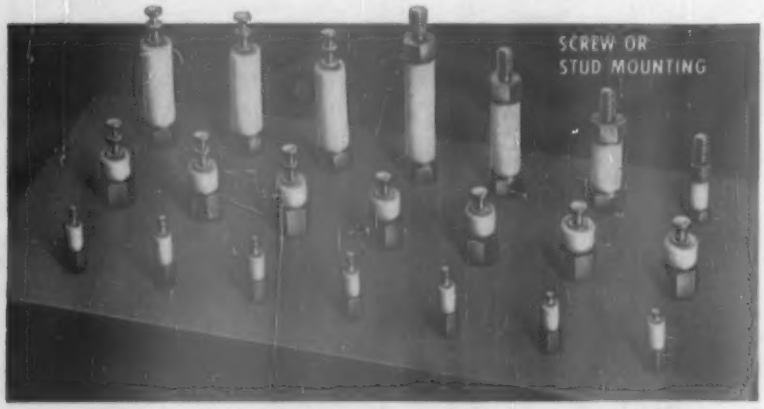

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EMPLOYMENT 89

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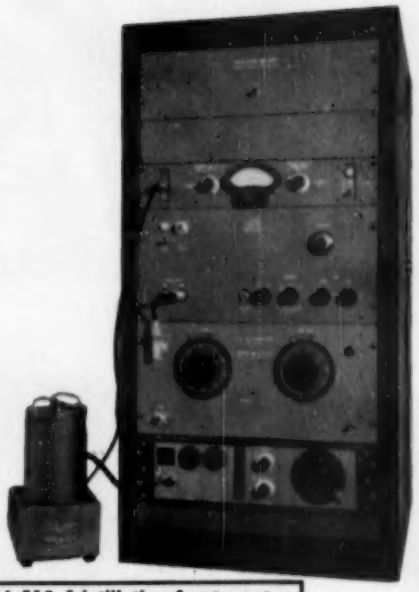

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